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RESEARCH ARTICLE

Evaluation of Development Policy through Water Environmental Carrying Capacity Analysis in North Kendeng Mountain, Indonesia

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Abstract. North Kendeng Mountain is an area with abundant limestone reserves, presenting tremendous potential for various applications, such as cement production, cosmetics, paint, and other commercial products. The region also serves as water resource storage, widely utilized for household use and crop irrigation. This unique combination of resources has created a contentious conflict between the local people supported by academicians, the government, and investors. The government and investors advocate the exploitation of the area's potential for commercial gains, favoring its use for industrial purposes. Meanwhile, the local people and academicians strongly advocate for conservation due to its environmental significance. To address these issues, a Strategic Environmental Assessment (SEA) was carried out for the North Kendeng ecosystem and revealed that the current spatial planning and mid-term development plans proposed by the provincial government and related regency governments leaned toward natural resource utilization, with a focus on mining activities. Therefore, this study aims to analyze the effect of implementing the government's policy and planning on water environmental carrying capacity (WECC). This is a descriptive study, which collected data using informal interviews, observation, and literature review. The qualitative data on development policy were analyzed with content analysis techniques, including descriptive, interpretative, and explanative. A comparison analysis was carried out to determine the interaction between the proposed development activities and the existing environmental condition based on WECC results, as well as to assess the policy orientation in North Kendeng Mountain Area. After comparing water demand and availability both with and without the government's policy, the results showed that the condition of WECC was deficient for all regencies, except the Lamongan regency. This indicated that the implemented regulation potentially worsened water deficits in all regencies. It was suggested that revising policy and updating planning were required to achieve sustainable utilization of the North Kendeng Mountain Area.

Keywords: development policy; limestone mining; spatial planning; water environmental carrying capacity

1. Introduction

The significance of environmental consideration in development policy is widely acknowledged as a crucial aspect of the decision-making and legal processes. However, in reality, it appears to have limited influence in driving development and planning decisions (Hadi et al., 2019). The current trend of development still prefers maximizing profit and growth, while disregarding the detrimental impact on natural resources. This attitude has led to a concerning negative correlation between natural resource abundance and growth (Sachs & Warner, 2001). According to a previous study, countries with abundant resources often experience various failures in the manufacturing industry (Amiri et al., 2019). One pivotal aspect that demands immediate attention from stakeholders is the concept of environmental carrying capacity. It is imperative to recognize and respect the threshold of mineral exploitation (Świąder et al., 2020), with particular emphasis on water, which stands as the most crucial element.

Water supply is undeniably the most crucial element for sustaining human livelihood, apart from the natural system. Despite its importance as a vital resource, ensuring its continued availability and maintaining sustainability has become a subject of concern, especially amidst the push for economic growth-oriented development. Water is an essential element of life, which maintains a stable quantity on the planet, but its consumable form has increasingly become scarce (Marganingrum, 2018).

Urban development is posing a significant threat to water reserves. The process of urbanization is marked by the expansion of built-up areas (Rudiarto et al., 2018). The need for rapid development has increased the demand in cement industries, where limestone are the most valuable primary resource. Consequently, limestone quarrying and industry have experienced unprecedented growth to support the "effort to prosperity" process. Limestone offer numerous benefits, such as producing additional material for purifying metals, creating cosmetic products, producing papers and other office supplies, and manufacturing foods and medicine (Bliss et al., 2012). Limestone mining industry has become one of the most preferable activities due to its economic profit potential through export activities while also fulfilling local needs. This has led to the intense exploration and exploitation of areas with abundant limestone reserves, leading to degradation due to the unsustainable pattern of natural resource utilization.

Several studies reported that this industry caused various environmental hazards (Ganapathi & Phukan, 2020), such as chemical and physical depletion of water resources (Masood et al., 2020), as limestones are stored in the karstic area, serving as the natural water reservoir. According to a recent report, the salinity of River Ribble, Yorkshire Dales National Park has increased due to intense limestone quarrying activities, but the impact is still complying with the regulation (Warren, 2013). However, this activity still affects water flow and reduces water table, both on the surface and in the groundwater of this famous salmon river. A study in East Jaintia Hills (9% of India's limestone reserve) showed that limestone mining caused deforestation, land degradation, pollution of surface water, and water scarcity. Despite the provision of employment opportunities and increased income for local people, this area still experienced acute water shortages, especially in the dry season, as well as increases in pH, EC, TDS, total hardness, alkalinity, calcium and sulphate concentrations (Eugene, 2014). In the Ashaka Area, Northeastern Nigeria, limestone mining and processing led to the accumulation of high concentrations of carbonate and bicarbonate from hand-dug wells, boreholes, surface water, mine ponds, and wastewater samples. This pollution is caused by the dissolution and weathering of bedrock, while the content of fluoride and heavy metals is due to the industry's activities (IA et al., 2016). Previous studies also established a connection between limestone mining and water shortages. The primary issues in Manihalla Village, Pakistan are dust and water shortages due to the industry (Haseeb et al., 2018). The reference cited in the study supports this finding that these problems are likely caused by limestone quarrying activities.

Development process as a political phenomenon necessitates an examination of changes in water carrying due to policy implementation, but this field is currently unexplored. Previous reports on water environmental carrying capacity (WECC) primarily focused on developing multi-temporal carrying capacity studies (Lu et al., 2017), creating spatial analysis (Zhou et al., 2017), and combining various mathematical models (Kang & Xu, 2012; Lu et al., 2017; Marganingrum, 2018; Y. Wang et al., 2018), or involving uncertainties using probability analysis method (Liu et al., 2012). Although existing studies often combine qualitative indicators in their calculation, the integration of both qualitative and quantitative analysis remains rare.

WECC is one of the most important tools in achieving sustainable development in a region (Kang & Xu, 2012). Furthermore, it is a crucial aspect in the issuance of permits for activities or programs. Derived from the well-known sustainable development paradigm, carrying capacity analysis is a vital component in development policy-making process, employed in environmental impact analysis to ensure sustainability through environmental planning and water pollutant control (Faludi, 2000; Liu et al., 2012). Various factors influence WECC, including the characteristics of water environmental and pollutants, as well as the spatial patterns of the pollutants (Liu et al., 2012). The application of a mathematical method aids in quantifying whether an activity's impact is still within environmental threshold or exceeding it. The main consideration is that the exponential growth of the human population requires a finite number of natural resources. Economic growth and development still depend on the ability and availability of natural resources (Meadows et al., 1972). Living within the constraints of natural limits is crucial as denying these limits can lead to disastrous consequences (Heinberg, 2018; Price, 1999). Vital resources, such as clean air for the lungs, nutritious foods to meet the need of the guts, and adequate water to hydrate the cells human body, are essential for human survival (Glasson & Marshall, 2007).

WECC is the most comprehensive method among the three dimensions in assessing water carrying capacity, with the other two being resources and ecology. Water resources carrying capacity is focused on inventorying potential resources that could be used for human life (Dou et al., 2015; Du et al., 2011; Naimi Ait-Aoudia & Berezowska-Azzag, 2016; Xiao-qing et al., 2012). Furthermore, the ecological dimension focuses on analyzing the natural system of water flow and recharge, regardless of technology and innovations (S. Wang et al., 2014). WECC is often considered the most comprehensive dimension as it integrates both natural and man-made aspects (Dsikowitzky et al., 2018; Jia, Cai, Chen, & Zeng, 2018; Kang & Xu, 2012; Lu et al., 2017; T. Wang & Xu, 2015).

WECC-based limestone mining phenomenon analysis has been studied in several regions, such as India, Nigeria, Pakistan, and China, but none has been carried out in Kendeng Karst, Indonesia. Previous studies in the Kendeng Region primarily focused on community movement (Hadi, Purnaweni, et al., 2020; Rokhmad, 2020), Strategic Environmental Assessment (SEA) (Hadi, Buchori, et al., 2020; Hadi et al., 2019), and petrographic analysis, which revealed a good quality reservoir and potential oil reserves Kendeng Karst (Rusdi et al., 2019). These studies were carried out to analyze policy of WECC, which referred to the ability of water to accept organic waste without polluting them, thereby maintaining the ecological balance (Wulandari, 2020). This is important because the local community still depends on Kendeng Karst the major supplier of clean water for agriculture and household needs, but mining activities in the area have caused flooding and landslides (Mojo et al., 2017). Therefore, this study aims to: (1) analyze development policy orientation in understanding how policy is directed towards conservation or utilization; (2) assess the impact of the existing policy towards the threat of water carrying capacity in limestone-abundant area; and (3) develop policy recommendation to ensure water security for the future generations.

The discussion in this paper article follows this structure: The background of the study, including the description of its urgency, is explained in this Introduction section. The following section describes the data, finding, and data analysis technique used in this study. Section 3 discusses all the results and their relevance with other studies. Within the third section, the structure follows the aim as mentioned in the previous paragraph. Furthermore, all the key points and the recommendation for future studies and future development policy are presented in detail in the Conclusion section. All the references are also mentioned in the last section (Section 5).

2. The Methods

Study Area

According to recent reports, Java Island accounts for a total of 55% of Indonesian national cement consumption (Lestari, 2022; Subiyanto, 2020). The island has 11,000 kilometers of limestone mountain, a tenth of all national's potential, which made limestone industries a growing sector on this island (Suhendra, 2017). As the demand for construction increased, the region had become one of the most preferred locations for limestone mining industry, the main resource of cement production.

One of the most important limestone mountain was located in the North Kendeng Mountain, as shown in Figure 1. The area administratively lied on two different provincial authorities, namely Central Java and East Java. Furthermore, it was specifically located around seven regencies, including Pati, Grobogan, Rembang, and Blora in Central Java, as well as Bojonegoro, Tuban, and Lamongan in East Java. Based on previous reports, these provinces had an area of 80,604 km^2 (BPS, 2021; Setyaningrum, 2022), while the Kendeng Mountain were 250 km long, with a maximum width of 40 km. Therefore, the maximum area reached 10,000 km^2 or 12% of the total area of the two provinces.

As shown in Figure 1, there were six karstic formations (written in the map as KBAK or *Kawasan Bentang Alam Karst*/ Karst Landscape Area) in the North Kendeng Mountains, which were named based on the regency they were situated upon, namely (1) KBAK Gresik/Lamongan; (2) KBAK Lamongan; (3) KBAK Rembang; (4) KBAK Rembang Blora; (5) KBAK Sukolilo; and (6) KBAK Tuban. The karst landscape area or the KBAK was also defined as part of the geological protected area that was included in the protected area (Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2012).

The karstic formations in this region were rich in limestone, which was indicated by the number of conical hills, the emergence of springs in rock crevices, and underground river flows with cave passages as corridors. Springs and underground river systems in the karst area of North Kendeng were eternal due to the process of active karst formation in this area, as evidenced by the presence of several springs (Wacana et al., 2011). The region also provides water storage for potable water and irrigation resources for local people. According to the official mining area map from the Ministry of Energy and Mineral Resources of the Republic of Indonesia, almost all the karstic areas in the North Kendeng Mountain were permitted for mining. As shown in Figure 2 below, a total of 96.15% or 2,029.83 sq km were dashed with purple fill color, indicating the *Wilayah Pertambangan* or Mining Area, which was defined as a region with the potential for mining. This region also accounted for approximately 5% of all areas of the regencies in Central Java, Indonesia. However, only 41.19 sq km was registered as *Wilayah Izin Usaha Pertambangan*/ WIUP or Mining Permit Area, a permit that was often given to corporations. The remaining 4% was stipulated as a protected forest area and forest area permitted for utilization.

This was a descriptive study, involving a qualitative analysis, which explored the incorporation of WECC into development policy. The method used was qualitative both in terms of substance and data availability. The qualitative method was chosen because it intertwined the substances of policy and WECC as well as the result of consultation with the considered theories. The scope of the study included policy taken by the government regarding the North Kendeng Mountain area and environmental and social implications of the implemented policy.

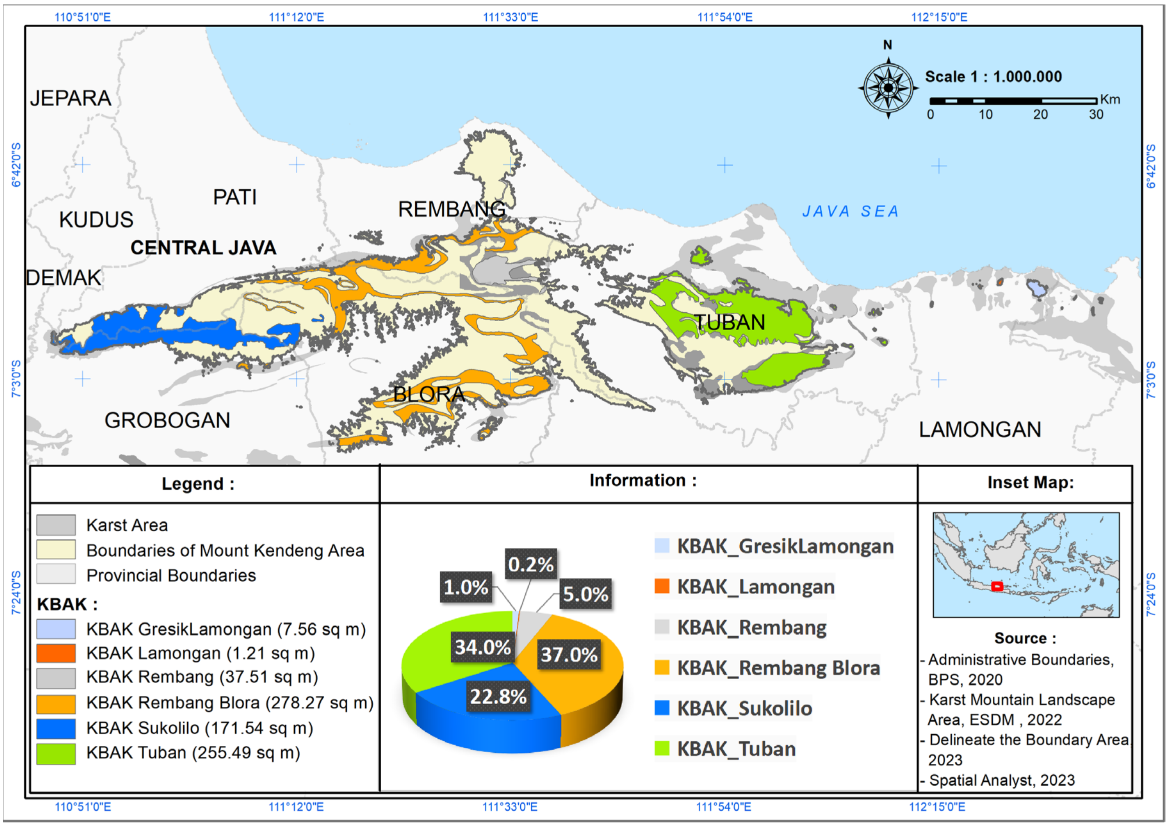

Figure 1. Map of Karst Landscape Area (*Kawasan Bentang Alam Karst/KBAK*) in North Kendeng Mountains
Source: Analysed from Ministry of Energy and Mineral Resources of the Republic of Indonesia (2023)

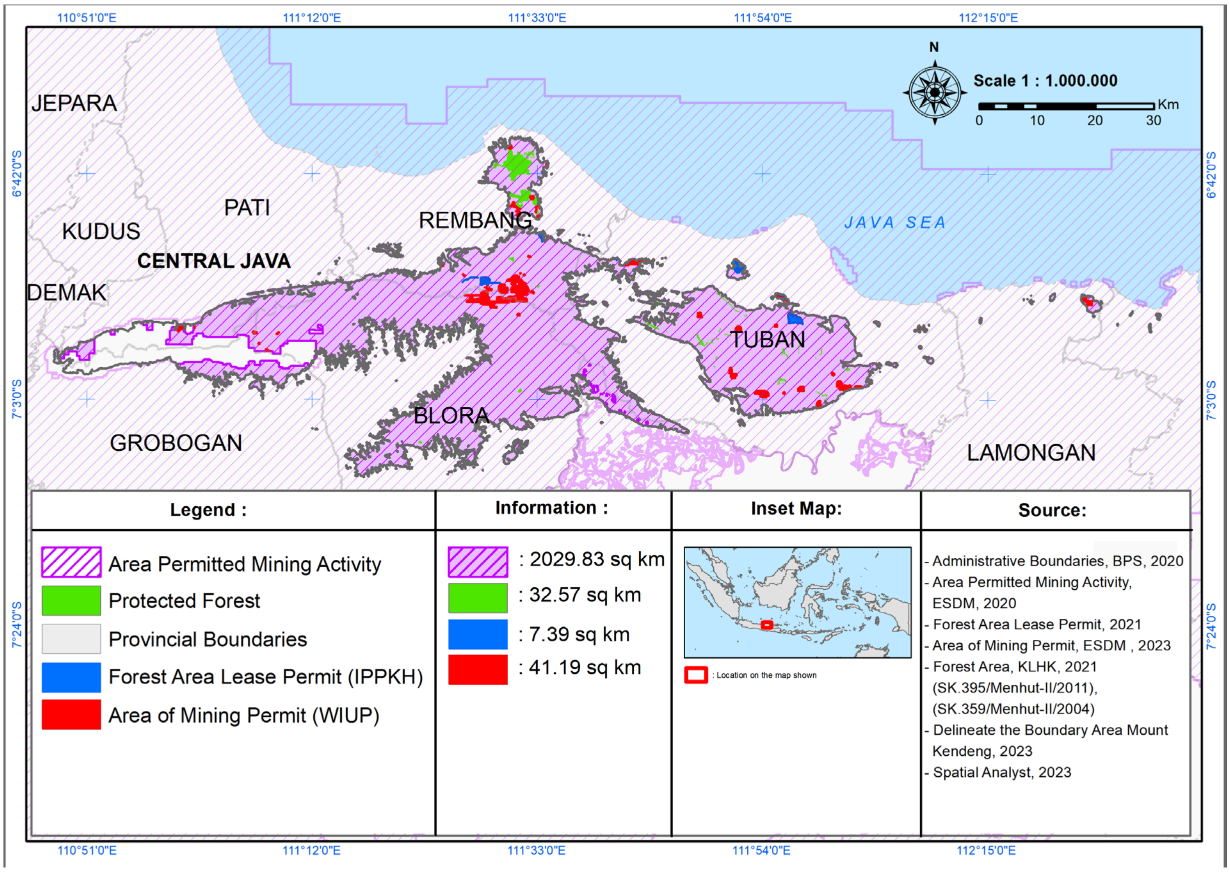

Figure 2. Map of Mining Permit Area in North Kendeng Mountains
Source: Mining Permit Map, Ministry of Energy and Mineral Resources of the Republic of Indonesia (2022a, 2022b) accessed from https://geoportal.esdm.go.id/minerba/ on 27th of February 2023

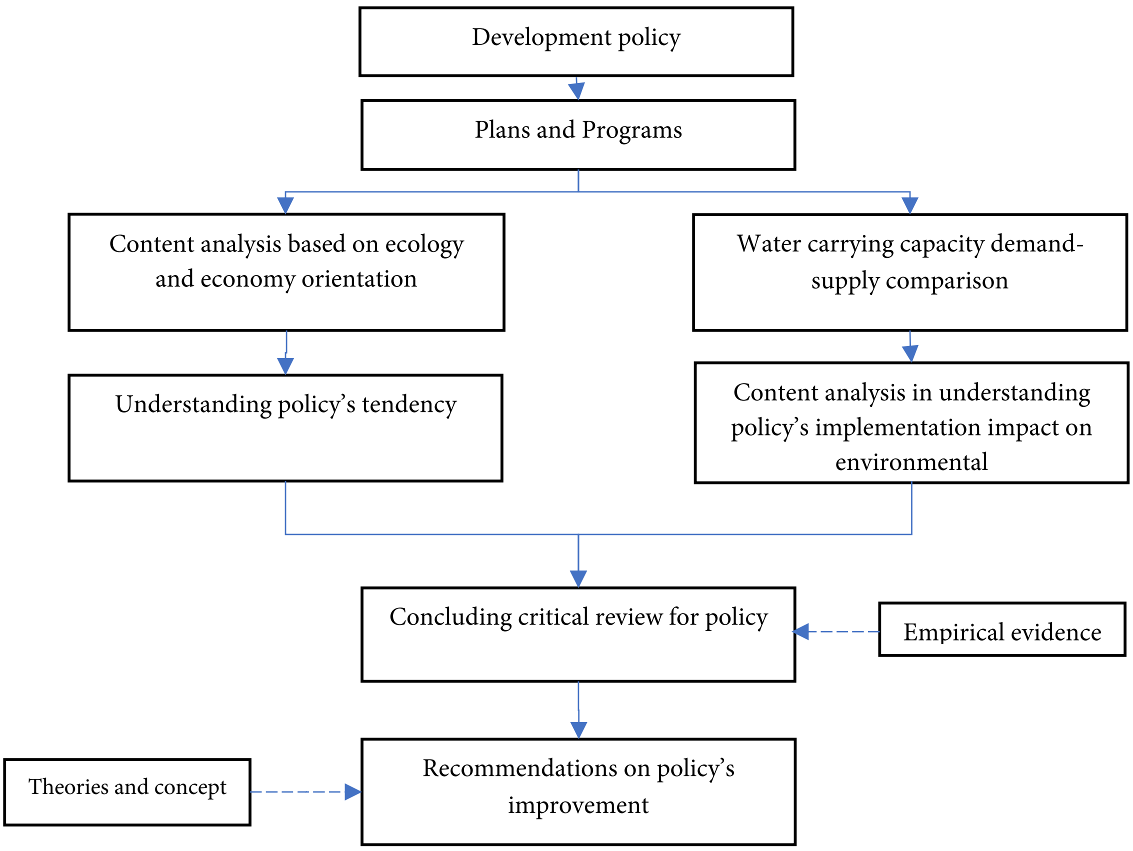

Figure 3. The research framework
Source: Author's analysis (2022)

Data Analysis and Collection Techniques

The data used in this study are presented in Table 1 below. Development plans (DP), spatial plans (SP), and SEA, which were implemented in the study area through the government's open data access website were collected. The programs, projects, and land utilization were reviewed qualitatively to portray the tendency. To understand the context, interview was conducted with government officials, experts, and some key informants from mining-impacted area.

For spatial data, the data were delineated based on the ecological boundary of the North Kendeng Mountain Region, as shown in Figure 1. However, due to data availability limitation, the regency delineation (region-based) data for the statistical related information, which had no spatial distribution information were also used.

After the data was collected, this study conducted a content analysis. This technique was commonly used to evaluate development policy. Content analysis was formerly used as a tool to understand how a theoretical concept was being interpreted into policy (Handayani et al., 2019), the comprehensiveness of policy in addressing environmental hazards (Hamdani et al., 2020), the capability of strategic planning in resolving land degradation (Oliveira et al., 2018), and developing inclusive recommendation in updating smart city strategies (Bednarska-Olejniczak et al., 2019).

Table 1. Development Policy

Name of Document	Types of Document*	Source	Level
Strategic Environmental Assessment of Utilization and Management of North Kendeng Mountain Area, 2017	SEA	Executive Office of the President & Ministry of Environmental and Forestry, Republic of Indonesia (2017)	National
Ministry of Energy and Mineral Resources Number 0398/K/40/MEM/2005 Concerning Designation of the Sukolilo Karst Landscape Area, Central Java	R	Ministry of Energy and Mineral Resources of the Republic of Indonesia (2005)	National
Ministerial Decree of Energy and Mineral Resources no 2641/K/40/MEM/2014 on the KBAK (Karst Natural Area) of Sukolilo (part North Kendeng area)	R	Ministry of Energy and Mineral Resources of the Republic of Indonesia (2014)	National
Government Regulation (PP) No. 13 of 2017 Amendments to Government Regulation Number 26 of 2008 Concerning National Spatial Plans	SP	President of the Republic of Indonesia (2017)	National
Decree of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 92.K/MB.01/ MEM.B/2022 Concerning Mining Areas of East Java Province	SD	(Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2022a)	Province
Decree of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 95.K/MB.01/ MEM.B/2022 Concerning Mining Areas of Central Java Province	SD	Ministry of Energy and Mineral Resources of the Republic of Indonesia (2022b)	Province
Regulation of the President of the Republic of Indonesia Number 28 of 2012 Concerning the Java-Bali Island Spatial Plan	SP	President of the Republic of Indonesia (2012)	Regional (Islands)
Central Java Provincial Regulation Number 6 of 2010 Concerning Provincial Spatial Planning 2009-2029	SP	Provincial Government of Central Java, Republic of Indonesia (2010)	Province
Regional Regulation of East Java Province Number 5 of 2012 Concerning Spatial Planning for East Java Province 2011-2031	SP	East Java Provincial Government, Republic of Indonesia (2012)	Province
Regional Regulation of Rembang Regency Number 14 of 2011 Concerning Spatial Plans for Rembang Regency 2011-2031	SP	Rembang Regency Government, Republic of Indonesia (2011)	Regency
Regional Regulation of Rembang Regency Number 1 of 2010 Concerning the Long Term Development Plan of Rembang Regency 2005-2025	DP	Rembang Regency Government, Republic of Indonesia (2010)	
Rembang Regency Regional Regulation Number 2 of 2016 Concerning the 2016-2021 Rembang Regency Medium-Term Development Plan	DP	Rembang Regency Government, Republic of Indonesia (2016)	Regency
Pati Regency Regional Regulation Number 05 of 2011 Concerning Pati Regency Spatial Planning 2010-2030	SP	Pati Regency Government, Republic of Indonesia (2011)	Province

Name of Document	Types of Document*	Source	Level
Grobogan Regency Regional Regulation Number 07 of 2012 Concerning the Grobogan Regency Spatial Plan for 2011-2031	SP	Grobogan Regency Government, Republic of Indonesia (2012)	Regency
Grobogan Regency Regional Regulation Number 11 of 2007 Concerning the Long-Term Development Plan for Grobogan Regency 2005-2025	DP	Grobogan Regency Government, Republic of Indonesia (2007)	Regency
Grobogan Regency Regional Regulation Number 10 of 2016 Concerning the Medium-Term Development Plan for the Grobogan Region of Grobogan Regency for 2016-2021	DP	Grobogan Regency Government, Republic of Indonesia (2016)	Regency
Regional Regulation of Blora Regency Number 18 of 2011 Concerning Spatial Planning for Blora Regency 2011-2031	SP	Blora Regency Government, Republic of Indonesia (2011)	Regency
Regional Regulation of Blora Regency Number 7 of 2011 Concerning Long-Term Development Plans for Blora Regency 2005-2025	DP	Blora Regency Government, Republic of Indonesia (2011a)	Regency
Tuban Regency Regional Regulation Number 09 of 2012 Concerning Spatial Plans for Tuban Regency 2012-2032	SP	Tuban Regency Government, Republic of Indonesia (2012)	Regency
Regional Regulation of Tuban Regency Number 05 of 2014 Concerning the Long-Term Regional Development Plan of Tuban Regency 2005-2025	DP	Tuban Regency Government, Republic of Indonesia (2014)	Regency
Tuban Regency Regional Regulation Number 24 of 2016 Concerning the Tuban Regency Medium Term Development Plan 2016-2021	DP	Tuban Regency Government, Republic of Indonesia (2016)	
Regional Regulation of Bojonegoro Regency Number 26 of 2011 Concerning Spatial Plans for Bojonegoro Regency 2011-2031	SP	Bojonegoro Regency Government, Republic of Indonesia (2011)	Regency

*DP : Development Planning ; SP : Spatial Plan ; SEA : Strategic Environmental Assessment ; R : Regulation ; SD : Spatial Data

Source: Author's analysis (2023)

3. Result and Discussion

Development Policy Orientation

Development was an act of maximizing the region's potential to enhance its prosperity. Furthermore, it covered various policy planning processes from various stakeholders and institutions. In Indonesia, development was also constructed as a multi-level process. There were, (i) national level; (ii) provincial level; (iii) municipal level; which often need to be detailed into (iv) special zone; (v) district; and (vi) village. The decision-making process mentioned above could be categorized as hierarchically structured, top-down decision-making from a centralized authority with a short-term orientation (M. B. Monteiro & Partidário, 2017).

Dunn (2000) reiterated that the kinds of decisions made by the government were linked with values guiding the process. In Indonesia, values perceived to be agreed upon nationwide were promulgated in Article 33 of the Constitutional Law 1945, that natural resources and any biodiversity upon it are utilized for the people's prosperity. The Constitution further mandated that the national economy must be based on the principle of sustainability, environmental friendliness, and self-sufficiency. This law was then considered as the national's basic value on economics and development. The well-known sustainable development values revealed that any development measures were not just for the people, but also for environmental's sustainability.

At policy and plan levels, the orientation of development had been more geared towards natural resource utilization rather than conservation. However, the regulation strictly stated how land utilization must consider environmental capacity condition. This could be seen in spatial planning at the national, provincial, and local levels regarding the North Kendeng Mountain Area in Central and East Java, where more space was allocated for mining.

The two policy that were predicted to cause environmental degradation, such as water shortage, included spatial planning (RTRW) and mid-term regional development planning (RPJMD). National spatial planning of Java and Bali revealed that the area of Juwana, Jepara, Kudus, Pati, Rembang, and Blora in Central Java was excellent for agriculture, mining, and fisheries. Meanwhile, the area of Tuban and Bojonegoro in East Java was excellent for tourism, industry, plantations, agriculture, fisheries, and mining. Central Java spatial planning (article 80) allocated these regions with an orientation towards mining activity. This was also true for East Java where Bojonegoro, Tuban, and Lamongan were used for mining.

According to recent reports, the mid-term provincial development planning (RPJMD) for the seven regencies did not address the following issues (1) risks of drought, flood, and illegal mining; (2) utilization and natural resource conservation was more oriented toward commodity development, often at the expense of environment; (3) did not take into account the land-use changes and environmental degradation that had occurred over the past twenty years; (4) the problems of water shortages had been addressed using infrastructure development rather than improving the function of the river basin, (5) the issue of agricultural land for food sustainability, even though the economic basis of all regencies was agriculture, (6) include policy dealing with illegal utilization of natural resources; and (7) space for public participation in the decision-making process was actually available, but it was treated as a procedural tool and not as a substantial one, where the relevant aspiration and interest were incorporated in the decision making.

This mechanism of decision-making was substantially categorized as hierarchically structured, top-down with centralized authority, and short-term orientation (M. B. Monteiro & Partidário, 2017). Hadi (2018) noted that Mid-term Regional Development Planning of Central Java and adjacent regencies tended to utilize this area for mining and other uses, and did not address environmental issues, specifically water shortages and massive land use changes causing changes in land cover, as well as heightened vulnerability and risk of environmental disaster.

Although the dichotomy between utilization for the economy and ecological conservation was outdated (Vörösmarty et al., 2018), the bias in developing natural resources at the expense of environmental degradation remained prevalent in current policy and practice. This was found in nature curse discourse where development policy tended to maximize the profit gained from natural resource utilization. However, the actual process caused degradation and the inhabitants did not get the prosperity desired. In mining industry, there was a new perspective intertwining this dichotomy. Sustainable mining capacity was a concept where economic profit was being maximized, while the ecological loss was minimized (Masood et al., 2020).

This kind of biased decision could be caused by socioeconomic conditions, as reported by Sheehy-Skeffington (2020). Choosing utilization or economic rationality over conservation or ecological rationality seemed more efficient in the short term. Meanwhile, it could increase urbanized activity that acted as environmental stressor (Duh et al., 2008), leading to increased environmental problems (Daly, 1977).

Decision-making processes that chose ecological benefits over economic rationality could only be achieved when humans had no other choice than to preserve the ecosystems. One such example could be the spikes in risk affecting the sustainability of human life. This perception was regarded as framing effect theory, stating that human decision-making processes were influenced by how the risk was framed and perceived. The higher the risk that could potentially affect people, the higher they tended to take proactive actions and make decisions adapting to the situations (Bhattachan et al., 2018).

The natural resource utilization for economic growth and development or economic rationality was not often detrimental as it was perceived. Furthermore, it could help to rationalize and simplify the complexity involved in environmental decision-making (Sedjo et al., 2007). This included quantifying environmental benefits by assessing the total economic value of forest conservation that could intertwine ecological rationality based on profitable activity for the ecosystem (Loomis et al., 2019). To take advantage of economic rationality, any method using a rational decision-making process must consider habitat sustainability as a priority to create a long-life period of human activity (Peng et al., 2019).

Transparency and inclusiveness in decision-making were also important principles to prevent this bias. Specifically, preventing a region from experiencing a nature curse involved providing an economic opportunity, which was environmentally sustainable and accepted by the local people (Lawer et al., 2017).

In the context of mining industry, apart from portraying the concept of sustainable mining capacity, it was also important to understand how the industry could achieve sustainable development. A review by Monteiro et al. (2019) concluded that mining sector could possibly contribute to at least three goals, namely (1) increasing job promotions (Goal 8); (2) reducing poverty (SDGs 1); and (3) decreasing hunger (SDGs 2). Meanwhile, it was emphasized that as this industry could not restore the environment, it could not help regions to achieve Goal 13, involving the impacts and crises caused by climate change.

Development policy must integrate economic, social, and environmental aspects theoretically and normatively. However, the implementation expressed in spatial planning and mid-term development planning, and also in programs and activities, was inconsistent with this principle. To keep policy on track toward sustainable development, there was a need to conduct studies on how this concept was being implemented to give input, recommendations, or revisions.

Impacts of Existing Policy towards Threatening WECC

At present, water resources in the North Kendeng Mountain area was stable, but still vulnerable (Hadi, 2018). The role of this karstic area in the natural water cycle was to regulate the absorption, storage, and release of rainwater. This natural process was expected to increase the stability of water availability. As shown in Figure 4, there were six groundwater basins or *Cekungan Air Tanah/CAT* in the North Kendeng Mountain Area, including (1) CAT Kudus; (2) CAT Lasem; (3) CAT Panceng; (4) CAT Surabaya-Lamongan; (5) CAT Tuban; and (6) CAT Watuputih. This showed the importance of mountain area being preserved as it had the role of serving as water recharge system for several regions.

The impact of development policy that overlooked WECC had been experienced in recent days. As reported by local people, there was flooding in early January 2023 in some areas around the North Kendeng Mountains. In Pati Regency, the flooding impacted more than 3,000 hectares of rice fields, leading to crop failure (Sumandoyo, 2023). However, during the dry season, it was observed that the rainfall rate decreased. The seasonal water shortage often occurred in areas where the people is highly relying on the karstic springwater for their daily needs and livelihood.

According to the Rembang Regency Statistical Bureau, the yearly average rainfall data fluctuated, and the trend showed a slight decrease from 2016 onwards (as shown in Figure 5). The data released by the National Agency on Disaster Management (2021) revealed that all regencies of the North Kendeng Mountain were at high risk for flooding, flash floods, and landslides, as shown in Table 2.

According to water balance analysis conducted at the study area by comparing the exponential projection of water demand/needs based on spatial planning with water availability from various sources (surface water, groundwater, water springs, etc), the SEA study predicted that in 2040, all regencies was likely to experience a deficit, as shown in the Table 3 below (Executive Office of the President & Ministry of Environment and Forestry, RI, 2017). Furthermore, the condition of WECC comparing the demand and availability

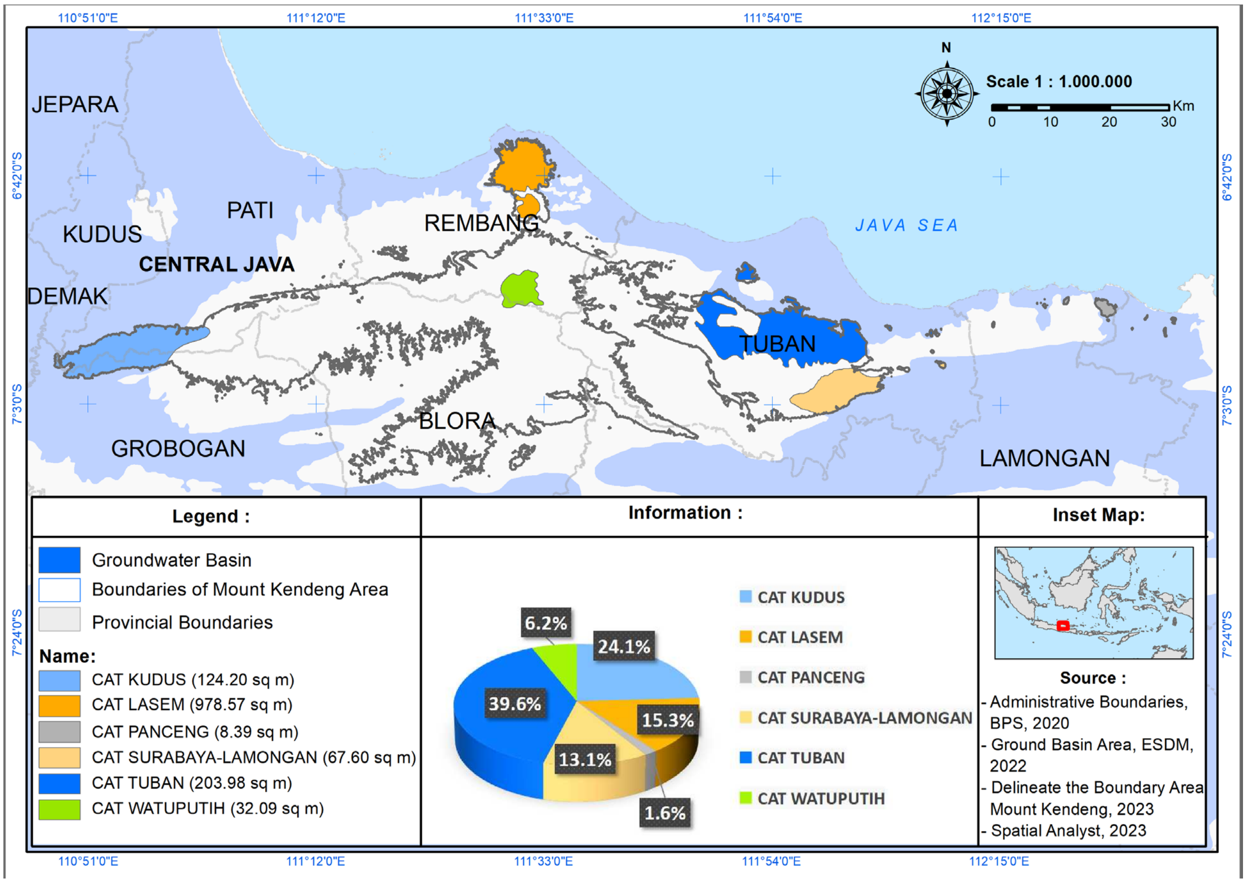

Figure 4. Spatial distribution of Groundwater Basin in North Kendeng Mountains Area
Source: Analyzed from the Groundwater Basin Map from the Ministry of Energy and Mineral Resources of the Republic of Indonesia (2017) as accessed from EMR's Geoportal https://geoportal.esdm.go.id/geologi/

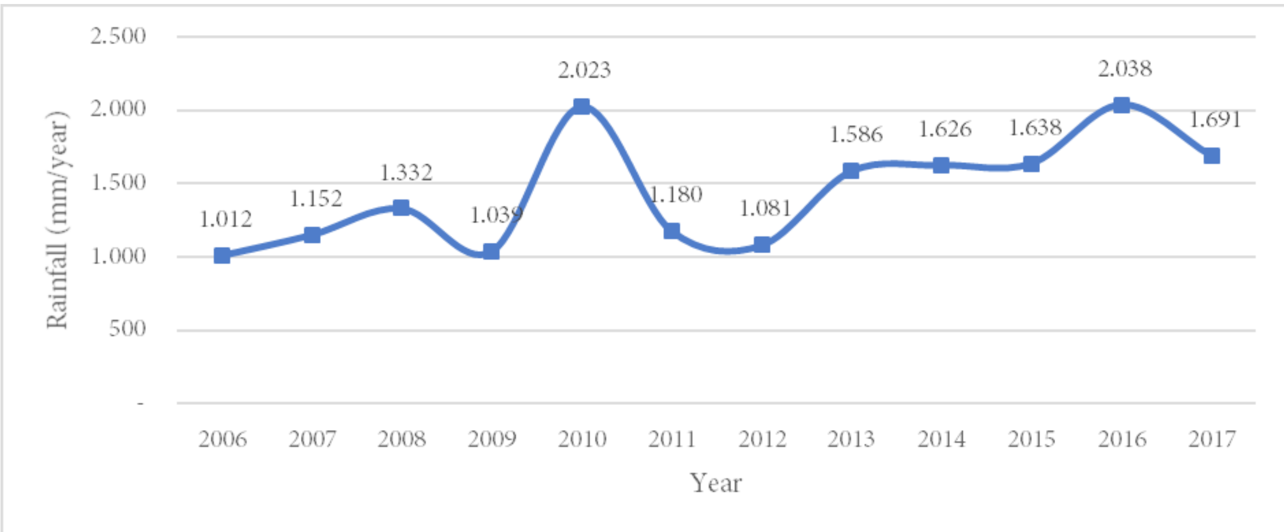

Figure 5. Average Yearly Rainfall Data of Rembang Regency
Source: Agriculture and Food Service of Rembang Regency as published in Rembang Regency Statistic Bureau's Official Website (https://rembangkab.bps.go.id/ accessed on 20th of March 2023)

both without policy and planning for all regencies had a deficit, except Lamongan regency. Analysis showed that the trend of deficit increased from 2015, 2020 to 2030, and 2040. The table also showed the condition of WECC with policy and planning, where the deficiency worsened for all regencies except Grobogan. Based on recent reports, Lamongan was likely to be greatly impacted in 2040.

These results were consistent with previous studies that Tuban Regency could experience water deficit in the future if the proposed plan related to development of the North Kendeng Mountain Area was implemented (LPPM IPB & Tuban Regency Government, Republic of Indonesia, 2014). As predicted by the official water resource agency, water needs in this area were likely to exceed availability by 2027 (Balai Besar

Table 2. Disaster Profile in North Kendeng Mountains Area

Regency	Disaster-impacted population (%)				
	Flood	Drought	Extreme Weather	Landslide	Forest Fires
Blora	44,17%	100,00%	66,11%	0,55%	32,93%
Grobogan	23,63%	100,00%	54,91%	0,43%	20,29%
Pati	53,41%	100,00%	49,14%	1,49%	18,91%
Rembang	80,50%	100,00%	46,37%	2,37%	23,94%
Bojonegoro	53,42%	100,00%	41,16%	0,70%	23,80%
Lamongan	45,44%	100,00%	35,17%	0,01%	15,40%
Tuban	72,40%	100,00%	15,86%	0,59%	28,43%

Source: Impacted population data per disaster taken from Indonesia Disaster Profile 2021 (National Disaster Agency, Republic of Indonesia, 2021), and Population Data is taken from Yearly Population Statistics (Statistic Bureau of Central Java, 2022; Statistic Bureau of East Java, 2023), percentage data is analyzed by authors by dividing impacted population with total population.

Table 3 Condition and prediction of WECC (million m^3/year) for domestic and irrigation uses for seven regencies in the districts covering the North Kendeng Mountain Area with the scenario of Policy, Planning, and Program (PPP), and without PPP.

Regencies	Grobogan	Pati	Rembang	Blora	Bojonegoro	Tuban	Lamongan	Total
Without PPP								
Availability*	941.1	804.0	1,243.7	2,216.9	416.1	2,464.6	378.7	8,465.0
Demand 2015**	1,172.5	1,265.4	1,740.9	2,375.7	535.5	2,937.4	360.2	10,387.6
Demand 2020	1,192.7	1,276.7	1,738.5	2,394.9	539.5	2,960.1	362.6	10,465.0
Demand 2030	1,245.5	1,307.2	1,735.3	2,446.0	550.0	3,020.7	369.2	10,673.9
Demand 2040	1,301.7	1,341.1	1,736.5	2,501.6	561.3	3,085.6	376.4	10,904.2
WECC 2015	-231.4	-461.4	-497.2	-158.8	-119.4	-472.8	18.5	-1,922.6
WECC 2020	-251.6	-472.8	-494.8	-178.0	-123.,4	-495.5	16.0	-2,000.0
WECC 2030	-304.4	-503.2	-491.7	-229.1	-133.9	-556.1	9.4	-2,208.9
WECC 2040	-360.6	-537.1	-492.8	-284.7	-145.2	-621.0	2.2	-2,439.2
With PPP								
Demand 2020	1,187.,8	1,278.1	1,739.6	2,396.8	541.5	2,971.4	364.1	10,479.3
Demand 2030	1,228.3	1,312.9	1,739.6	2,454.5	557.5	3,063.2	374.9	10,730.8
Demand 2040	1,272.6	1,351.9	1,745.1	2,517.3	575.2	3,165.2	387.2	11,014.6
WECC 2020	-246.7	-474.2	-495.9	-179.9	-125.4	-506.8	14.5	-2,014.3
WECC 2030	-287.2	-508.9	-495.9	-237.6	-141.4	-598.6	3.7	-2,265.7
WECC 2040	-331.5	-548.0	-501.4	-300.4	-159.0	-700.7	-8.5	-2,549.6

*Assumed in this study that the rainfall depth data for water availability is around 2,000-2,800 mm/year (Balai Besar Wilayah Sungai Pemali-Juana, 2010)

**The demand analysis is conducted through population exponential projection and land use area changes as stated in spatial plan (Executive Office of the President & Ministry of Environment and Forestry, RI, 2017)12/17/2015 2:51:00 PM

Source: Executive Office of the President & Ministry of Environment and Forestry, Republic of Indonesia (2017)

Wilayah Sungai Pemali-Juana, 2010). These findings were also in line with Malakooti (2012) that choosing economic rationality over ecological rationality seemed more efficient in the short term, but caused problems in the middle and long term.

SEA studies reported by the Executive Office of the President & Ministry of Environment and Forestry, Republic of Indonesia (2017) found that the potential for land use change in the North Kendeng area reached 132,480 hectares. This indicated that approximately 48% of the area was likely to be used for mining. This was expected to decrease the infiltration coefficient of water by 30%. The SEA study also reported that water resource at North Kendeng was currently utilized for irrigation (60%) and domestic use (40%). Based on predictions, the potential of water loss for domestic use and agriculture needs reached 262,959,035 and 394,438,552 cubic meters per year, respectively. The loss recorded from crop failure was predicted at Rp (Indonesian Currency) 1,377,229,581,704 per year for agricultural land of 27,545 hectares.

These facts corresponded with the flash flood occurring in Pati and Rembang, in December 2022. The flood was as deep as 1-2 meters, impacting more than 4,000 houses, and lasting for more than two weeks (Utami, 2023; Yasa, 2023). The impacted neighborhood is presented in Figure 6 below. This disaster caused crop failure with a loss estimation of 123 billion rupiahs or 8.2 million USD (Utami, 2023). According to

Figure 6. Flooded neighborhood in Pati Regency, December 2022
Source: Picture from Raditya Mahendra Yasa for Kompas.id as published in (Utami, 2023)

local experts and environmentalists, this flood was caused by mining activity, which disrupted the forest and its ecosystem in North Kendeng Mountain (Salam, 2023; Wicaksono, 2023).

Policy recommendations

WECC as an assessment tool had been derived into the Indonesian development policy legal process. Sustainable development had been adopted as policy for development in Indonesia since 1982 by promulgating Act 4 of 1982 on Basic Principles of Environmental Management. The spirit of sustainable development had also been internalized in the broad outlines of State Policy, the National Development Program, and the Long-term Development Plan. According to Article 34 par. 4 of Law Number 26/2007 on Spatial Planning, any kind of space utilization must be compatible with the carrying capacity of the environment. Although the concept of WECC was well derived into regulation, the regulation was already prepared to force any development policy to become aware of environmental conditions. However, several studies often found that there was a gap between what must be done and what was actually done.

Santoso et al., (2014) reported that integrating SEA and spatial planning was challenging as it involved two different stakeholders and institutions. The results also revealed that the SEA could not fully describe how environmental carrying capacity accommodated any land utilization plan. This problematic integration influenced Hadi et al., (2019) to consider SEA as a powerless document that was lacking in influence.

According to recent reports, there were already efforts to create changes in the existing development policy. This was carried out by the local community who were aware that this policy did not have transparency or inclusiveness, which were considered the important aspects of preventing nature curse (Hadi, Purnaweni, et al., 2020). Although they were internally divided into two major groups, the first group supported or rejected mining industry-oriented development policy. The second group preferred to allocate policy towards environmental conservation rather than being exploited for economic growth (Hadi, Purnaweni, et al., 2020). The community stated that mining industry in their area already had bad impacts, such as water shortages (Hidayatullah et al., 2016)· and floods. This result of socio-spatial learning had driven them to continue pursuing any conceivable way to deconstruct and change the orientation of development policy.

Although the academicians, legal aid institutions, and several other environmental conservation organizations had been joining the force and struggling for more than 10 years (Sumandoyo, 2023), they could not still change policy. Mining industry had obtained permission to carry out their various activities. This was not considered a failure but showed that the local people had the ability and endurance to fight for the sake of environmental sustainability. However, the people's participation was not included in the decision-making process. The inclusiveness of the decision-making process must be improved to ensure that programs or orientations mentioned in development policy was more grounded and accepted by the local community.

A similar pattern had also been shown in another case, where a private company named PT TMS (Tambang Mas Sangihe or Gold Mining Sangihe) corporation based in Canada obtained an operation permit using environmental license issued in September 2020 by the Ministry of Mining and Energy and from the Office of Environment of North Sulawesi Province Government. As reported by Prasetyadi (2021, 2022, 2023), the environmental permit was sued by the local community to the Administrative Court for two reasons. First, Sangihe Island, where the gold mining was located, was a small Island, with a land area of only 73,698 hectares. This area was not suitable for mining because it could be adversely degraded, thereby affecting local people working as fishermen. Second, the issuance of environmental permit had legal defects because the process of making Environmental Impact Assessment (EIA) was not followed by public participation as required by the Act no 32 of 2009 on environmental protection and management. The lawsuit by the local community was granted by the Administrative Court in Jakarta and strengthened by the decision of the Supreme Court dated January 2022. However, after the decision of the Administrative and Supreme Courts, the Ministry of Mining and Energy submitted an appeal. This was an indication the issuance of the permit was inappropriate and the decision did not align with sustainable development principles. Compared to the North Kendeng case, the issuance of environmental permit and operational permit by the government at Sangihe showed that they were more economically oriented.

According to Act number 11 of 2020 on Job Creation Law (JCL), which amended 74 regulations to facilitate the ease of doing business, development policy was more oriented toward economic growth. As noted by Hadi et al., (2023), in promoting investment, the Indonesian government simplified the business license procedure by providing an exemption on previously existing procedures. Project proponents were exempted from the obligation to conduct EIA if their projects were aligned with the land utilization policy expressed in a detailed spatial plan. This policy potentially threatened environmental sustainability because only 10 regencies and cities in Indonesia were equipped with detailed SP. Furthermore, environmental carrying capacity and capability as observed from the North Kendeng Mountains case, were rarely incorporated into spatial planning. The requirements were considered an obstacle in initiating business due to its high cost and long procedure. The JCL changed policy by issuing an operational license without an EIA. It was predicted that the implementation of JCL could increase environmental degradation and resource depletion, thereby contributing to global greenhouse gas emissions. Another evidence that spatial planning was not based on environmental carrying capacity was observed in Pati Regency. Local residents of the North Kendeng Mountain area opposed the plan to build a cement factory in the region. The community believed that the area was water reservoir irrigating hundred hectares of rice fields and provided water for household use. However, the area was eventually allocated for mining in Pati Regency 2011-2031 spatial plan.

4. Conclusion

In conclusion, WECC in all regencies in North Kendeng Mountain was likely to become more deficit and worsen in 2030 and 2040 if the current policy and planning were implemented. All regencies, specifically the districts bordering the North Kendeng Mountain Area, were at high risk of ecological disasters, such as flooding, flash floods, and landslides. Consequently, these policy must be revised to limit mining activities in the region below environmental threshold. Increasing emphasis on restoring and restabilizing degraded land for water recharge function was also required to shift development orientation from natural resources utilization to conservation as the North Kendeng Mountain Area was originally stipulated as a protected area. Based on the nature of development policy as a political process, there was a need to portray the political situation of the region. The social network of elite and key stakeholders could also help in understanding this issue. There was a more advanced discussion on water carrying capacity, where the threshold was considered a dynamic value rather than a fixed limit. This study considered carrying capacity as a fixed value, indicating the need for further exploration of how policy could affect the dynamics of the threshold.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Amiri, H., Samadian, F., Yahoo, M., & Jamali, S. J. (2019). Natural resource abundance, institutional quality and manufacturing development: Evidence from resource-rich countries. In *Resources Policy* (Vol. 62, pp. 550–560). https://doi.org/10.1016/j.resourpol.2018.11.002

Balai Besar Wilayah Sungai Pemali-Juana. (2010). *Pola Pengelolaan Sumber Daya Air Wilayah Sungai Jratunseluna*. Direktorat Sumber Daya Air, Kementerian Pekerjaan Umum Republik Indonesia. https://sda.pu.go.id/assets/files/2010_Pola%20PSDA%20Jratunseluna.pdf

Bednarska-Olejniczak, D., Olejniczak, J., & Svobodová, L. (2019). Towards a Smart and Sustainable City with the Involvement of Public Participation—The Case of Wroclaw. *Sustainability*, *11*(2), 332. https://doi.org/10.3390/su11020332

Bhattachan, A., Jurjonas, M. D., Moody, A. C., Morris, P. R., Sanchez, G. M., Smart, L. S., Taillie, P. J., Emanuel, R. E., Seekamp, E. L., & Carolina, N. (2018). Sea Level Rise Impacts on Rural Coastal Social-Ecological Systems and The Implications for Decision-making. *Environmental Science and Policy*, *90*(December 2017), 122–134. https://doi.org/10.1016/j.envsci.2018.10.006

Bliss, J. D., Hayes, T. S., & Orris, G. J. (2012). Limestone-A crucial and versatile industrial mineral commodity. *USGS*, *August*, 1–3.

Blora Regency Government, Republic of Indonesia. (2011a). *Peraturan Daerah Kabupaten Blora Nomor 7 Tahun 2011 Tentang Rencana Pembangunan Jangka Panjang Daerah Kabupaten Blora Tahun 2005-2025*. https://www.blorakab.go.id/index.php/public/download

Blora Regency Government, Republic of Indonesia. (2011b). *Peraturan Daerah Kabupaten Blora Nomor 18 Tahun 2011 Tentang Rencana Tata Ruang Wilayah Kabupaten Blora Tahun 2011-2031*. https://pusdataru.jatengprov.go.id/dokumen/

RTRW-Prov/11-Kab-Blora/Perda-No-18-Th-2011-ttg-RTRW-Kab-Blora.pdf

Bojonegoro Regency Government, Republic of Indonesia. (2011). *Peraturan Daerah Kabupaten Bojonegoro Nomor 26 Tahun 2011 Tentang Rencana Tata Ruang Wilayah Kabupaten Bojonegoro Tahun 2011-2031*. Pemerintah Kabupaten Bojonegoro.

BPS. (2021). *Luas Daerah dan Jumlah Pulau Menurut Provinsi 2021*. Geografi Dan Iklim. https://www.bps.go.id/

Daly, H. E. (1977). *Steady-state economics: The economics of biophysical equilibrium and moral growth*. W.H. Freeman.

Dou, M., Ma, J. X., Li, G. Q., & Zuo, Q. T. (2015). Measurement and assessment of water resources carrying capacity in Henan Province, China. *Water Science and Engineering*, *8*(2), 102–113. https://doi.org/10.1016/j.wse.2015.04.007

Dsikowitzky, L., Wulp, S. A. Van Der, Ariyani, F., Hesse, K. J., Damar, A., & Schwarzbauer, J. (2018). Transport of Pollution from The Megacity Jakarta into The Ocean: Insights from Organic Pollutant Mass Fluxes Along The Ciliwung River. *Estuarine, Coastal and Shelf Science*, *215*(January), 219–228. https://doi.org/10.1016/j.ecss.2018.10.017

Du, M., Xu, Z., Peng, L., Zhu, Y., Xu, X., Min, D., Zhenghe, X., Limin, P., Yunhai, Z., Xiufeng, X., Du, M., Xu, Z., Peng, L., Zhu, Y., & Xu, X. (2011). Comprehensive evaluation of water resources carrying capacity of Jining City. *Energy Procedia*, *5*, 1654–1659. https://doi.org/10.1016/j.egypro.2011.03.282

Duh, J., Shandas, V., Chang, H., & George, L. A. (2008). Rates of urbanisation and the resiliency of air and water quality. *Science of The Total Environment*, *400*(1–3), 238–256. https://doi.org/10.1016/j.scitotenv.2008.05.002

Dunn, W. N. (2000). *Analisis Kebijakan Publik (Terjemahan)*. Gadjah mada University Press.

East Java Provincial Government, Republic of Indonesia. (2012). *Regional Regulation of East Java Province Number 5 of 2012 Concerning Spatial Planning for East Java Province 2011-2031*. https://bappeda.jatimprov.go.id/dokumen-perencanaan/

Eugene, L. R. (2014). Degradation in Water Quality due to Limestone Mining in East Jaintia Hills, Meghalaya, India. In *Int. Res. J. Environment Sci. International Science Congress Association* (Vol. 3, Issue 5).

Executive Office of the President, & Ministry of Environment and Forestry, RI. (2017). *Kajian Lingkungan Hidup Strategis (KLHS) Kebijakan Pemanfaatan dan Pengelolaan Pegunungan Kendeng yang Berkelanjutan Tahap II*. Ministry of Environment and Forestry, Republic of Indonesia.

Faludi, A. (2000). The Performance of Spatial Planning. *Planning Practice and Research*, *15*(4), 299–318. https://doi.org/10.1080/713691907

Ganapathi, H., & Phukan, M. (2020). Environmental Hazards of Limestone Mining and Adaptive Practices for Environment Management Plan. In R. M. Singh, P. Shukla, & P. Singh (Eds.), *Environmental Processes and Management: Tools and Practices* (Vol. 91, pp. 121–134). Springer International Publishing. https://doi.org/10.1007/978-3-030-38152-3_8

Glasson, J., & Marshall, T. (2007). *Regional Planning* (1st ed.). Routledge.

Grobogan Regency Government, Republic of Indonesia. (2007). *Peraturan Daerah Kabupaten Grobogan Nomor 11 Tahun 2007 Tentang Rencana Pembangunan Jangka Panjang Daerah Kabupaten Grobogan Tahun 2005-2025*. https://www.grobogan.go.id/dokumen/rpjpd

Grobogan Regency Government, Republic of Indonesia. (2012). *Grobogan Regency Regional Regulation Number 07 of 2012 Concerning the Grobogan Regency Spatial Plan for 2011-2031*. https://www.grobogan.go.id/dokumen/rtrw?download=16:rtrw-kabupaten-grobogan-2011-2031

Grobogan Regency Government, Republic of Indonesia. (2016). *Peraturan Daerah Kabupaten Grobogan Nomor 10 Tahun 2016 Tentang Rencana Pembangunan Jangka Menengah Daerah Grobogan Kabupaten Grobogan Tahun 2016-2021*. http://bappeda.grobogan.go.id/images/2019_RPJMD_2016_2021.pdf

Hadi, S. P., Buchori, I., Purnaweni, H., Prabawani, B., & Adiwibowo. (2020). Strategic environmental assessment (SEA) in a conflict situation: A case study on North Kendeng Mountain Area, Central Java, Indonesia. *Asian Journal of Microbiology and Biotechnology*, *22*(1), 15–23.

Hadi, S. P., Hamdani, R. S., & Roziqin, A. (2023). A sustainability review on the Indonesian job creation law. *Heliyon*, *9*. https://doi.org/10.1016/j.heliyon.2023.e13431

Hadi, S. P., Purnaweni, H., Hadiyanto, & Prabawani, B. (2018). Sustainable use of water resource at North Kendeng Mountain, Central Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *191*(1). https://doi.org/10.1088/1755-1315/191/1/012005

Hadi, S. P., Purnaweni, H., & Prabawani, B. (2019). The Powerless of Strategic Environmental Assessment (SEA): A Case Studies of North Kendeng Mountain Area, Central Java, Indonesia. *E3S Web of Conferences*, *125*(201 9), 9–11. https://doi.org/10.1051/e3sconf/201912502014

Hadi, S. P., Purnaweni, H., Prabawani, B., & Hamdani, R. S. (2020). Community Movement for Sustainable Use of Natural Resources: Case study of North Kendeng Mountain Area, Central Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *448*(1), 012069. https://doi.org/10.1088/1755-1315/448/1/012069

Hamdani, R. S., Hadi, S. P., Rudiarto, I., & Purnaweni, H. (2020). Do we care enough? Revisiting land subsidence and coastal spatial planning policy in Semarang, Indonesia. *E3S Web of Conferences*, *202*(August), 06005. https://doi.org/10.1051/e3sconf/202020206005

Handayani, W., Fisher, M. R., Rudiarto, I., Sih Setyono, J., & Foley, D. (2019). Operationalizing resilience: A content analysis of flood disaster planning in two coastal cities in Central Java, Indonesia. *International Journal of Disaster Risk Reduction*, *35*(May 2018), 101073. https://doi.org/10.1016/j.ijdrr.2019.101073

Haseeb, Z., Rana, A., Naseer, N., Aftab, A., Haseeb, A., Chaudhry, M. N., & Majid, M. (2018). Monitoring of Environment, Health and Socio-Economic Impacts of Limestone Quarrying Near Chakwal, Pakistan. *Pakistan Journal of Science*, *70*(4), 2018.

Heinberg, R. (2018). *We Are Exceeding Earth's Carrying Capacity. Denying It Is Suicidal*. https://qz.com/1347735/how-many-people-can-earth-support-its-carrying-capacity-isnt-infinite/

Hidayatullah, Umar, Rini, H. S., & Arsal, T. (2016). Analisis Peta Konflik Pembangunan Pabrik PT. Semen Indonesia Di Kecamatan Gunem Kabupaten Rembang. *Solidarity: Journal of Education, Society and Culture*, *5*(1), 10–21.

IA, O., Amadi, A., Olashinde, P., Sabo, S., & Okoye, N. (2016). Impacts of Limestone Mining and Processing on Water Quality in Ashaka Area, Northeastern Nigeria. *Development Joumal of Science and Technology Research*, *5*(1), 47–62.

Jia, Z., Cai, Y., Chen, Y., & Zeng, W. (2018). Regionalization of water environmental carrying capacity for supporting the sustainable water resources management and development in China. *Resources, Conservation and Recycling*. https://doi.org/10.1016/j.resconrec.2018.03.030

Kang, P., & Xu, L. (2012). Water Environmental Carrying Capacity Assessment of an Industrial Park. *Procedia Environmental Sciences*, *13*(2011), 879–890. https://doi.org/10.1016/j.proenv.2012.01.082

Lawer, E. T., Lukas, M. C., & Jørgensen, S. H. (2017). The neglected role of local institutions in the 'resource curse' debate. Limestone mining in the Krobo region of Ghana. *Resources Policy*, *54*(March), 43–52. https://doi.org/10.1016/j.resourpol.2017.08.005

Lestari, R. (2022, January 24). Berhasil Tumbuh 5,9 Persen, Konsumsi Semen 2021 Masih Belum Pulih. *Bisnis*. https://ekonomi.bisnis.com/read/20220124/257/1492534/berhasil-tumbuh-59-persen-konsumsi-semen-2021-masih-belum-pulih

Liu, R. M., Sun, C. C., Han, Z. X., Chen, L., Huang, Q., Chen, Y. X., Gao, S. H., & Shen, Z. Y. (2012). Water environmental capacity calculation based on uncertainty analysis: A case study in the Baixi watershed area, China. *Procedia Environmental Sciences*, *13*, 1728–1738. https://doi.org/10.1016/j.proenv.2012.01.166

Loomis, J. J., Knaus, M., & Dziedzic, M. (2019). Integrated Quantification of Forest Total Economic Value. *Land Use Policy*, *84*(March), 335–346. https://doi.org/10.1016/j.landusepol.2019.03.018

LPPM IPB, & Tuban Regency Government, Republic of Indonesia. (2014). *Studi Daya Dukung dan Daya Tampung Lingkungan Kabupaten Tuban, Provinsi Jawa Timur*. Pemerintah Kabupaten Tuban.

Lu, Y., Xu, H., Wang, Y., & Yang, Y. (2017). Evaluation of water environmental carrying capacity of city in Huaihe River Basin based on the AHP method: A case in Huai'an City. *Water Resources and Industry*, *18*(October), 71–77. https://doi.org/10.1016/j.wri.2017.10.001

Malakooti, B. (2012). Decison Making Process: Typology, Intelligence, and Optimization. *Journal of Intelligent Manufacturing*, *23*(3), 733–746. https://doi.org/10.1007/s10845-010-0424-1

Marganingrum, D. (2018). Carrying Capacity of Water Resources in Bandung Basin. *IOP Conference Series: Earth and Environmental Science*, *118*(1), 012026. https://doi.org/10.1088/1755-1315/118/1/012026

Masood, N., Hudson-Edwards, K., & Farooqi, A. (2020). True cost of coal: Coal mining industry and its associated environmental impacts on water resource development. *Journal of Sustainable Mining*, *19*(3). https://doi.org/10.46873/2300-3960.1012

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The Limits to Growth* (D. H. Meadows, Ed.; First). Universe Books.

Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2005). *Ministry of Energy and Mineral Resources Number 0398/K/40/MEM/2005 Concerning Designation of the Sukolilo Karst Landscape Area, Central Java*. Ministry of Energy and Mineral Resources of the Republic of Indonesia. https://jdih.esdm.go.id/peraturan/kepmen%200398%202005.pdf

Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2012). *Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 17 of 2012 concerning Designation of Karst Landscape Areas*. https://peraturan.bpk.go.id/Home/Details/143826/permen-esdm-no-17-tahun-2012#:~:text=Permen%20ESDM%20No.%2017%20Tahun,Alam%20Karst%20%5BJDIH%20BPK%20RI%5D

Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2014). *Decree of the Minister of Energy and Mineral Resources No. 2641 K/40/MEM/2014 concerning Designation of the Sukolilo Karst Landscape Area, Central Java*. Ministry of Energy and Mineral Resources of the Republic of Indonesia. https://jdih.esdm.go.id/peraturan/Kepmen-esdm-2641-2014.pdf

Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2017). *Peraturan Menteri Energi dan Sumber Daya Mineral Nomor 02 Tahun 2017 Tentang Cekungan Air Tanah di Indonesia*. Kementerian Energi dan Sumber Daya Mineral Republik Indonesia. https://jdih.esdm.go.id/index.php/web/result/1612/detail

Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2022a). *Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 92.K/MB.01/MEM.B/2022 Tentang Wilayah Pertambangan Provinsi Jawa Timur*. https://jdih.esdm.go.id/storage/document/Kepmen%20ESDM%20No.%2092.K-MB.01-MEM.B-2022.pdf

Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2022b). *Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 95.K/MB.01/MEM.B/2022 Tentang Wilayah Pertambangan Provinsi Jawa Tengah*. https://jdih.esdm.go.id/storage/document/Kepmen%20ESDM%20No.%2095.K-MB.01-MEM.B-2022.pdf

Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2023, January 19). *Peta Kawasan Bentang Alam Karst Republik Indonesia* [Geoportal]. ESDM One Map: Exploring Energy and Mineral Resources of Indonesia. https://geoportal.esdm.go.id/home/map/geologi

Mojo, E., Hadi, S. P., & Purnaweni, H. (2017). Sedulur sikep's environmental wisdom in conservation of North Kendeng mountains Sukolilo. *Advanced Science Letters*, *23*(3), 2504–2506. https://doi.org/10.1166/asl.2017.8657

Monteiro, M. B., & Partidário, M. R. (2017). Governance in Strategic Environmental Assessment: Lessons from the Portuguese practice. *Environmental Impact Assessment Review*, *65*(1), 125–138. https://doi.org/10.1016/j.eiar.2017.04.007

Monteiro, N. B. R., da Silva, E. A., & Moita Neto, J. M. (2019). Sustainable development goals in mining. *Journal of Cleaner Production*, *228*, 509–520. https://doi.org/10.1016/j.jclepro.2019.04.332

Naimi Ait-Aoudia, M., & Berezowska-Azzag, E. (2016). Water resources carrying capacity assessment: The case of Algeria's capital city. *Habitat International*, *58*, 51–58. https://doi.org/10.1016/j.habitatint.2016.09.006

National Disaster Agency, Republic of Indonesia. (2021). *Indonesia Disaster Profile 2021*. National Disaster Agency, Republic of Indonesia. https://gis.bnpb.go.id/arcgis/apps/experiencebuilder/experience/?id=a65571ee7eb043ed8607db888d044df9

Oliveira, E., Tobias, S., & Hersperger, A. M. (2018). Can strategic spatial planning contribute to land degradation reduction in urban regions? State of the art and future research. *Sustainability (Switzerland)*, *10*(4). https://doi.org/10.3390/su10040949

Pati Regency Government, Republic of Indonesia. (2011). *Pati Regency Regional Regulation of 2011 Concerning Pati Regency Spatial Planning 2010-2030*. https://jdih.jatengprov.go.id/dc/downloads/produk_hukum/kab_pati/perda/2011/1106_perda_5_tahun_2011.pdf

Peng, L., Deng, W., Zhang, H., Sun, J., & Xiong, J. (2019). Focus on economy or ecology? A three-dimensional trade-off based on ecological carrying capacity in southwest China. *Natural Resource Modeling*, *32*(2), 1–16. https://doi.org/doi.org/10.1111/nrm.12201

Prasetyadi, K. O. (2021, August 18). Tambang Emas di Sangihe, Semua yang Perlu Kita Ketahui. *Kompas*. https://interaktif.kompas.id/baca/tambang-emas-di-sangihe-semua-yang-perlu-kita-ketahui/

Prasetyadi, K. O. (2022, September 7). PT TMS Ngotot Bertahan di Sangihe. *Kompas*. https://www.kompas.id/baca/nusantara/2022/09/07/pt-tms-ngotot-bertahan-di-sangihe

Prasetyadi, K. O. (2023, January 16). Kasasi Ditolak, Kontrak Karya PT Tambang Mas Sangihe Harus Dicabut. *Kompas*. https://www.kompas.id/baca/nusantara/2023/01/16/ma-tolak-kasasi-kontrak-karya-pt-tambang-mas-sangihe-harus-dicabut

President of the Republic of Indonesia. (2012). *Peraturan Presiden Republik Indonesia Nomor 28 Tahun 2012 Tentang Rencana Tata Ruang Pulau Jawa-Bali*. Pemerintah Pusat Republik Indonesia. https://tataruang.atrbpn.go.id/sitarunas/dokumen?id=5

President of the Republic of Indonesia. (2017). *Government Regulation (PP) No. 13 of 2017 Amendments to Government Regulation Number 26 of 2008 concerning National Spatial Plans*. Central Government of Republic of Indonesia. https://peraturan.bpk.go.id/Home/Details/51463

Price, D. (1999). Carrying capacity reconsidered. *Population and Environment*, *21*(1), 5–26. https://doi.org/10.1007/BF02436118

Provincial Government of Central Java, Republic of Indonesia. (2010). *Central Java Provincial Regulation Number 6 of 2010 concerning Provincial Spatial Planning (RTRWP) 2009-2029*. https://jdih.jatengprov.go.id/mobile/inventariasi-hukum/view/perda-nomor-6-tahun-2010-1

Rembang Regency Government, Republic of Indonesia. (2010). *Peraturan Daerah Kabupaten Rembang Nomor 1 Tahun 2010 Tentang Rencana Pembangunan Jangka Panjang Kabupaten Rembang Tahun 2005-2025*. Pemerintah Kabupaten Rembang. https://rembangkab.go.id/haribawana/uploads/2017/00/rpjpd2005-2025/RPJPD-Rembang-2005-2025.pdf

Rembang Regency Government, Republic of Indonesia. (2011). *Regional Regulation of Rembang Regency Number 14 of 2011 concerning Spatial Plans for Rembang Regency 2011-2031*. https://jdih.rembangkab.go.id/perda-no-14-2011-rencana-tata-ruang-wilayah-rtrw-kab-rembang-tahun-2011-2031/

Rembang Regency Government, Republic of Indonesia. (2016). *Peraturan Daerah Kabupaten Rembang Nomor 2 Tahun 2016 Tentang Rencana Pembangunan Jangka Menengah Kabupaten Rembang Tahun 2016-2021*. https://bappeda.blorakab.go.id/packages/upload/portal/files/RPJMD%202016-2021%20Full.pdf

Rokhmad, A. (2020). Configuration and the role of community leaders in the conflict of natural resources of limestone mining for the cement industry in Rembang Indonesia. *International Journal of Energy Economics and Policy*, *10*(2), 521–528. https://doi.org/10.32479/ijeep.8321

Rudiarto, I., Handayani, W., & Setyono, J. S. (2018). A Regional Perspective on Urbanization and Climate-Related Disasters in the Northern Coastal Region of Central Java, Indonesia. *Land*, *7*(1), 34. https://doi.org/10.3390/land7010034

Rusdi, U. Y. K., Siregar, A. Y., & Triwigati, P. T. (2019). Deep Water Play Characteristics of Middle Miocene Kerek Limestone in Western Kendeng Zone, Java: Challenges and Chances for Future Exploration Based on Outcrop Studies. *The 15th HISAS*, 14–18.

Sachs, J. D., & Warner, A. M. (2001). The curse of natural resources. *European Economic Review*, *45*(4–6), 827–838. https://doi.org/10.1016/S0014-2921(01)00125-8

Salam, H. (2023, January 17). Banjir Terus Terjadi, Masyarakat Kendeng Surati Presiden. *Kompas*. https://www.kompas.id/baca/humaniora/2023/01/17/masyarakat-peduli-kendeng-surati-presiden-menyusul-banjir-akibat-tambang-dan-deforestasi

Santoso, E. B., Erli H, K. D. M., Aulia, B. U., & Ghozali, A. (2014). Concept of Carrying Capacity: Challenges in Spatial Planning (Case Study of East Java Province, Indonesia). *Procedia - Social and Behavioral Sciences*, *135*, 130–135. https://doi.org/10.1016/j.sbspro.2014.07.336

Sedjo, R. A., Berry, K., Charnley, G., Eberstadt, N. N., Glantz, M. H., Loewen, E. P., Moore, T. G., Opie, J., Rutherford, F. J., Seitz, F., Shabman, L., Shugart Jr., H. H., Sproull, R. L., Teta, M. J., Trivelpiece, A. W., & Vidaver, A. K. (2007). *Environmental Economics Volume 1: The Essentials* (Vol. 1). The Environmental Literacy Council.

Setyaningrum, P. (2022). Daftar 34 Provinsi di Indonesia dan Luas Wilayahnya. *Kompas.Com*.

Sheehy-skeffington, J. (2020). The Effects of Low Socioeconomic Status on Decision-making Processes. *Current Opinion in Psychology*, *33*, 183–188. https://doi.org/10.1016/j.copsyc.2019.07.043

Statistic Bureau of Central Java. (2022). *Yearly Population Projection and Sensus*. Statistic Bureau of Central Java. https://jateng.bps.go.id/site/resultTab

Statistic Bureau of East Java. (2023). *Yearly Population Projection and Sensus*. Statistic Bureau of East Java. https://jatim.bps.go.id/site/resultTab

Subiyanto, E. (2020). The Relationship of Cement Consumption and Economic Growth: An Updated Approach. *European Research Studies Journal*, *XXIII*(3), 280–295.

Suhendra. (2017, January 4). *Pabrik Semen Mengepung Pulau Jawa*. Tirto.Id. https://tirto.id/pabrik-semen-mengepung-pulau-jawa-b9Vx

Sumandoyo, A. (2023, January 19). Petani Kendeng Surati Jokowi Bahas Kerusakan Alam karena Tambang. *Narasi*. https://narasi.tv/read/narasi-daily/petani-kendeng-surati-jokowi-bahas-kerusakan-alam-karena-tambang

Świąder, M., Szewrański, S., & Kazak, J. K. (2020). Environmental Carrying Capacity Assessment—The Policy Instrument and Tool for Sustainable Spatial Management. *Frontiers in Environmental Science*, *8*(November). https://doi.org/10.3389/fenvs.2020.579838

Tuban Regency Government, Republic of Indonesia. (2012). *Peraturan Daerah Kabupaten Tuban Nomor 09 Tahun 2012 Tentang Rencana Tata Ruang Wilayah Kabupaten Tuban Tahun 2012-2032*. https://jdih.tubankab.go.id/produkhukum/produkhukum-1097

Tuban Regency Government, Republic of Indonesia. (2014). *Peraturan Daerah Kabupaten Tuban Nomor 05 Tahun 2014 Tentang Rencana Pembangunan Jangka Panjang Daerah Kabupaten Tuban Tahun 2005-2025*. Pemerintah Kabupaten Tuban. https://peraturan.bpk.go.id/Home/Details/55290/perda-kab-tuban-no-5-tahun-2014

Tuban Regency Government, Republic of Indonesia. (2016). *Peraturan Daerah Kabupaten Tuban Nomor 24 Tahun 2016 Tentang Rencana Pembangunan Jangka Menengah Daerah Kabupaten Tuban Tahun 2016-2021*. Pemerintah Kabupaten Tuban. https://tubankab.go.id/files/file2share/perda-nomor-24-tahun-2016-tentang-rpjmd-kab.-tuban-2016-2021.pdf

Utami, K. D. (2023, January 16). Lebih dari Dua Pekan Pati Terendam Banjir. *Kompas*. https://www.kompas.id/baca/nusantara/2023/01/16/lebih-dari-dua-pekan-pati-terendam-banjir-upaya-jangka-panjang-disiapkan

Vörösmarty, C. J., Rodríguez Osuna, V., Cak, A. D., Bhaduri, A., Bunn, S. E., Corsi, F., Gastelumendi, J., Green, P., Harrison, I., Lawford, R., Marcotullio, P. J., McClain, M., McDonald, R., McIntyre, P., Palmer, M., Robarts, R. D., Szöllösi-Nagy, A., Tessler, Z., & Uhlenbrook, S. (2018). Ecosystem-based water security and the Sustainable Development Goals (SDGs). *Ecohydrology & Hydrobiology*, *18*(4), 317–333. https://doi.org/10.1016/j.ecohyd.2018.07.004

Wacana, P., Rodialfallah, A., Chandra, F., Mesah, D., & Raimon, R. (2011). Study of The Potential of Karst Region in North Kendeng, The Districts of Grobogan and Pati. *Asian Trans-Diciplinary Karst Confeence 2011*, 471.

Wang, S., Xu, L., Yang, F., & Wang, H. (2014). Assessment of water ecological carrying capacity under the two policies in Tieling City on the basis of the integrated system dynamics model. *Science of the Total Environment*, *472*, 1070–1081. https://doi.org/10.1016/j.scitotenv.2013.11.115

Wang, T., & Xu, S. (2015). Dynamic successive assessment method of water environment carrying capacity and its application. *Ecological Indicators*. https://doi.org/10.1016/j.ecolind.2014.12.002

Wang, Y., Zhou, X., & Engel, B. (2018). Water environment carrying capacity in Bosten Lake basin. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2018.07.202

Warren, G. (2013). *The Effects of Limestone Quarrying on The River Ribble in The Yorkshire Dales National Park*. University of Central Lancashire.

Wicaksono, W. M. (2023, January 27). Pemerintah Diminta Lakukan Moratorium Pertambangan untuk Selamatkan Kendeng. *Kompas*. https://www.kompas.id/baca/nusantara/2023/01/27/pemerintah-diminta-lakukan-moratorium-pertambangan-untuk-selamatkan-kendeng

Wulandari, L. (2020). The Pollution index and carrying capacity of the upstream Brantas River. *g g* O., Qi, Y. I., Chun-lan, H. E.,

& Hong-hui, Y. (2012). Scenarios Simulation on Carrying Capacity of Water Resources in Kunming City. *Procedia Earth and Planetary Science*, *5*, 107–112. https://doi.org/10.1016/j.proeps.2012.01.018

Yasa, R. M. (2023, March 16). Gunung Kendeng dan Banjir Pantura Timur. *Kompas*. https://www.kompas.id/baca/foto/2023/03/16/gunung-kendeng-dan-banjir-pantura-timur

Zhou, X.-Y., Lei, K., Meng, W., Khu, S.-T., Zhao, J., Wang, M., & Yang, J. (2017). Space–time Approach to Water Environment Carrying Capacity Calculation. *Journal of Cleaner Production*, *149*, 302–312. https://doi.org/10.1016/J.JCLEPRO.2017.02.110