

A sustainable development strategy for mining industries in Citatah karst area in Bandung Basin

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Abstract. Citatah karst area is located in the western margin of Bandung Basin, as the only mining area within the basin. However, the pressure from environmentalists to preserve the karst area and change the use of land to become a conservation area or geopark is very high. The study aims to define the strategy to manage karst land in urbanizing areas to support sustainable development. The method of study includes policy and stakeholder analyses. Further analysis will be based on Spatial Multi Criteria Evaluation to apply land suitability analysis to seek the possibility of the Citatah karst area as geotourism and mine tourism. Karst area is an environmental complex system. Broad research to understand human-altered karst landscapes, karst ecosystems, karst disturbance, karst hydrology and also to manage karst lands in urbanizing areas in sustainable manners are needed. The provincial government agency has a master plan to develop the Citatah karst areas like agriculture, tourism, home industry, etc. The research result will support the plan on how to develop an assessment of the geosite and mining site present in Citatah karst area using multi criteria evaluation.

1. Introduction

Geologically, the Citatah karst area (CKA) was formed about 20-30 million years ago in the western part of Bandung Basin. Karst is formed from soluble limestones or dolomite. The area does not only have geological uniqueness but also archaeology. Pawon cave is the first site for the oldest of ancient humankind in west Java province. The surrounding area of the cave in Pawon hill is famous as a stone garden, one of the new tourism objects for those areas, and even, on January 1, 2020, an article from the online national newspaper, The Jakarta Post said the garden seems like an oasis among mining area that attracts not only local tourist but also geological expert.

Recently, there are several locations of a mining site in CKA (Figure 1). Mining has been started even since the colonial era. The mining sites include marble, limestone, andesite, and sand quarries. The mining industries have high pressure from environmentalists who want to preserve the area as a conservation area. The conflict between miners and environmentalists seems to rise when the provincial government of west Java has a plan to make zonation for CKA, because some areas of mining will be zoned as preservation areas [1]. However, on the other hand, some mining areas have started a post-mining land use program, it's called the agrotourism revegetation program, the goal is to develop fruit and vegetable crops in former mining areas [2].



Since the conflict in the karst area is becoming a national issue. The Ministry of Energy and Mineral Resources who has authority on geology and mining supervision released The Minister Regulation No.17/2012, as the conflict solution and guidance for karst area zonation. The regulation encourages local governments to actively investigate and delineate karst areas then the central government will be assigned the area as a conservation area.

Karst systems are considered an extremely complex system, because of several geological and hydrological characteristics, they can be considered among the most fragile and vulnerable environments in the world, the karst covers 10 to 20% of the earth's surface and provides 40 to 50% of the world's drinking water [3]. The case of mining industries in the CKA tends to have a great impact not only on the environment but also on urban development in West Bandung Regency. Therefore, there is the need for more integrated research to understand human-altered karst landscapes, to repair karst ecosystems, to measure karst disturbance and sustainability, to manage karst lands in urbanized and urbanizing areas, and to assess changes in karst hydrology [3].

The study's aim is to define a strategy to manage karst land in urbanizing areas to support sustainable development. The study will explore the possibilities of mining industries on sustainable development goals (SDG) related to environmental issues: SDG6 – Clean Water and Sanitation, and SDG15 – Life on Land of 17 goals at Sustainable Development Goals directly related to the land use at karst area. The contribution of mine on sustainable development must minimize environmental impacts as long as its lifecycle, from exploration to reclamation [4]. Geotourism at mining sites is getting attention from all stakeholders in the CKA, as one solution for the preservation of mining-geoheritage [5]. Geotourism and mine tourism potential in the CKA will be assessed by effective sustainable development criteria [6]. A detailed assessment of the geosites and mining sites is needed to develop strategies to make compatibility between geotourism and current mining operation, despite mining activities probably can create a difficult situation [7].

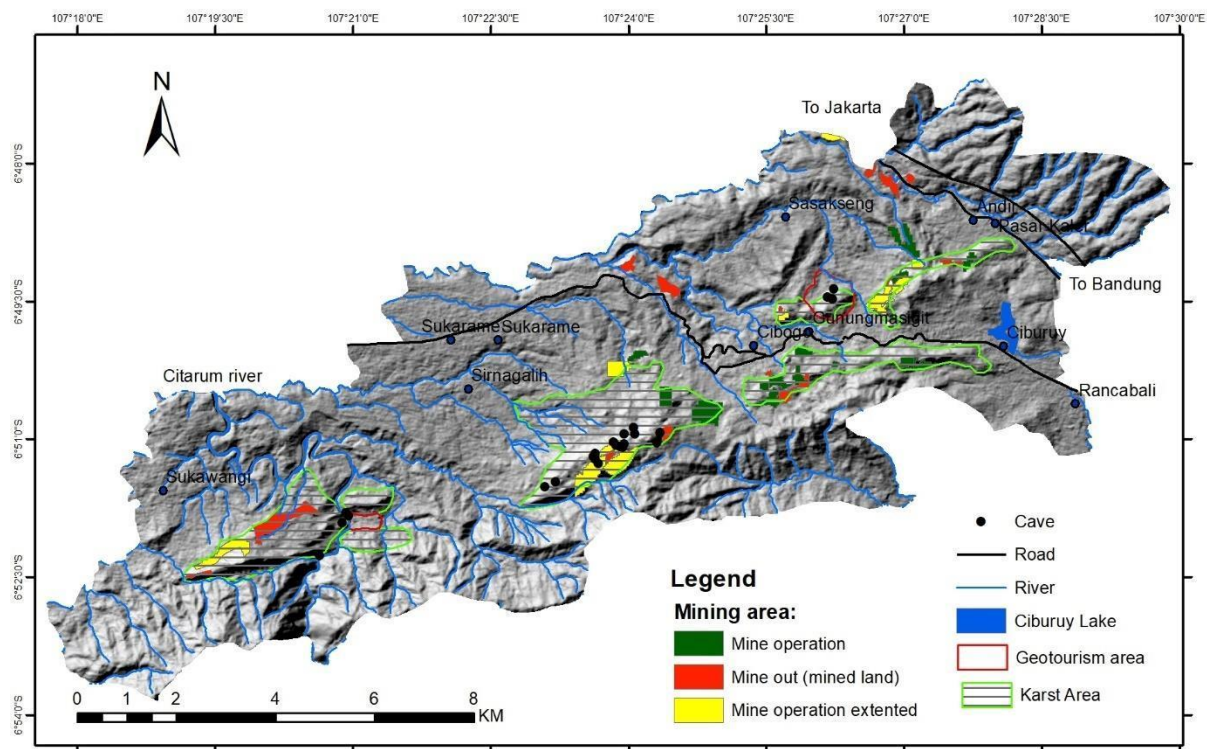


Figure 1. The status of mining operations in the Citatah karst area (CKA) (source: Energy and Mineral Resources Service, West Java Province and DEMNAS – Geoinformation Spatial Agency).

2. Material and Methods

2.1. Study area

Based on The Government Regulation No. 26/2008 (No.13/2017) about the National Spatial Plan, the Bandung Basin is a strategic region in national contexts because the urban areas of the Bandung Basin have three important roles at the national level; economic development, environmental protection, and urban development. Geologically, the Bandung Basin is an intermontane basin surrounded by mountain ranges and volcanoes. The total area of the Bandung Basin, about 2300 km², spans 60 km and 40 km from west to east and from north to south directions respectively, covering an area from 650 m to 2400 m above sea level as the peak [8].

Bandung Basin is very important since it is the location of 4 main cities or Greater Bandung including Bandung city, Cimahi City, West Bandung Regency, and Bandung Regency, the four cities are also famous as Bandung Metropolitan Area (BMA). Bandung City is famous as a services city and high education center, the total population is 3 2,510,103 in 2020. Cimahi City is the center of textile industries and food processing industries with a total population of about 620393 in 2020. Bandung regency is the center of textile industries, agriculture, plantation, and mining with a population of about 3,831,505 in 2020, and West Bandung Regency is the center of agriculture, plantation, agrotourism, industry, and mining with a population of about 1,714,982 in 2020 (Figure 2). The strategic position of Bandung Basin is stated by Presidential Decree of Indonesia No.45/2018, the spatial planning for urban areas of Bandung Basin that covers 5 urban areas and 85 district areas including all districts of Bandung Regency, West Bandung Regency, Cimahi City, Bandung City, and five districts of Sumedang Regency.

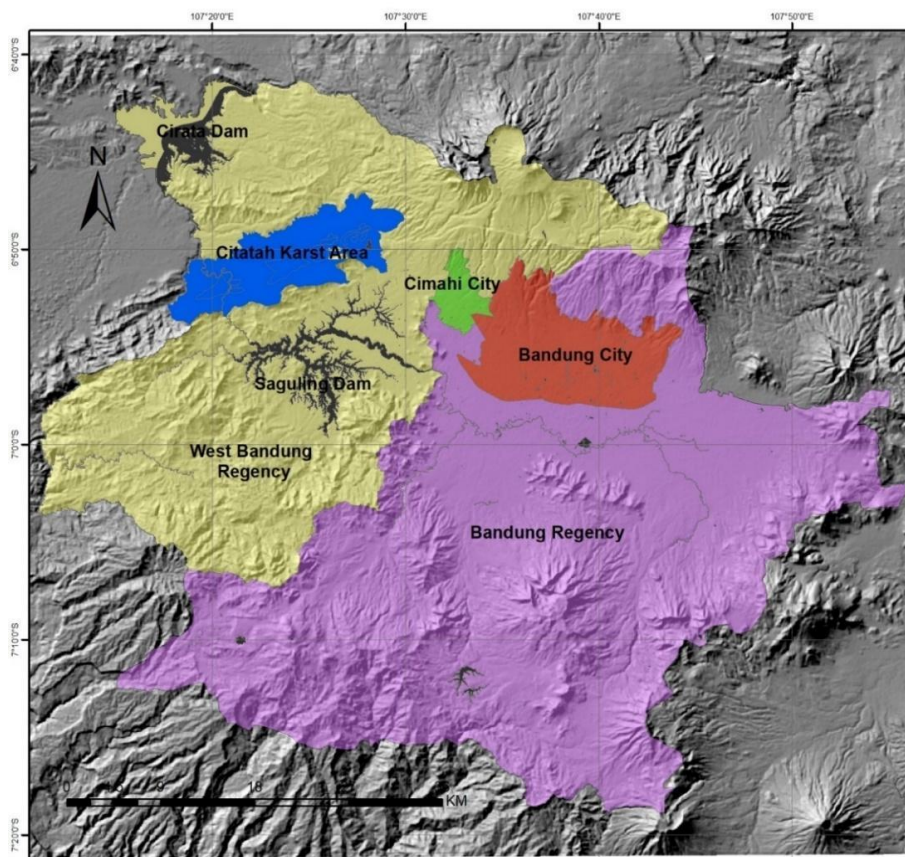


Figure 2. Bandung Basin covers four cities; Bandung City, Cimahi City, West Bandung Regency, and Bandung Regency. CKA as case studies is located in West Bandung Regency (source: DEMNAS – Geoinformation Spatial Agency).

Bandung Basin is rich in geothermal energy resources and environmental resources because it has volcanoes and beautiful landscapes. For mineral resources, the areas have nonmetal mineral deposits. In the west Java province, there are potential resources of metallic minerals such as gold, silver, copper, zinc, lead, iron sand, manganese, and titan sand (Table 1). Based on Indonesia Government Regulation Law No. 4/2009 (Law No.3/2020) about coal and mineral mining, the mineral is divided into radioactive mineral, metal mineral, nonmetal mineral, and stones. Based on Indonesia National Standard (SNI) 13-4688-1998, nonmetal minerals are divided into building materials, industrial minerals, ceramic materials, and gemstones. In Bandung Basin, especially in Bandung Regency, there is andesite deposit in Banjaran, sulphur in Ciwidey, trass in Cicalengka and Cikancung. Furthermore, in West Bandung Regency, andesite in Cipatik, Situwangi, Cililin, and Gunung Pabeasan, sulphur in Gunung Tangkuban Perahu, Oker in Batunagri, trass in Batureog and limestones in Padalarang, Citatah. In some areas of Bandung and West Bandung Regency, there are possibilities of the occurrences of gold and silver [9].

Nonmetal Mineral	Deposit (Ton)
Andesite	53,671,838.01
Limestones	11,070,098.32
Marble	19,916,651.41
Sandstone	6,152,787.72
Quartz Sand	714.98
Clay	143,005.84
Trass	2,016,115,752.20

Table 1. Mineral deposit in Bandung dan Bandung Barat Regency in 2012 [10].

2.2. Mining contribution on sustainable development

There are 17 sustainable development goals (SDG) and 169 targets based on the Millennium Development Goal (MDG) in September 2015 from the United Nations, the agenda to be achieved in 2030 [11,12]. The mining companies have an opportunity to contribute to all 17 SDGs. The mining companies must synchronize their operations from beginning to end with the SDGs. The three goals relating to environmental sustainability, social inclusion, and economic development. Table 2 shows the starting points to apply sustainable development in Mining [13]. In addressing environmental, social, and economical sustainability, the mining and minerals industry also faces the main challenge for the sector to demonstrate that it contributes to the welfare and wellbeing of the current generation, without compromising the potential of future generations for a better quality of life [14].

Table 2. Starting point for the application of sustainable development in Mining [13].

Starting Point	Sustainable Development Goal (SDG)
Environmental Sustainability	SDG6 – Clean Water and Sanitation, and SDG15 – Life on Land: Mining industry development needs access to land and water, providing high impacts on lands and natural resources should be avoided. SDG7 – Energy Access and Sustainability and SDG13 – Climate Action: Mining operations are energy and emissions-intensive, providing an opportunity for greater efficiency or extending access to energy.
Social Inclusion	SDG1 – Completion Poverty, SDG5 – Gender Equality, and SDG10 – Reduced Inequalities. Mining can generate great revenues for governments in the form of taxes, royalties, and dividends. It can be used for economic and social development, besides providing jobs opportunities and local business from linkages industries. The companies can work with local communities to understand the mines' actual and potential impacts either positive impacts or negative impacts. The companies can support the process of participatory decision-making related to the mining operations, the equitable allocation of benefits, and the resolution of conflict. The company can identify opportunities to

Starting Point	Sustainable Development Goal (SDG)
	strengthen the voice of marginalized groups (women), to ensure that inequalities are reduced by the direct or indirect economic opportunities from mining.
	SDG16 – Peace, Justice and Strong Institutions: Mining also can contribute to peaceful societies and the rule of law. Such as preventing and remedying conflict between company and community, praising human rights and the rights of indigenous peoples, delivering transparent reporting of revenue flows, preventing illicit transfers of funds to public officials or other persons, and supporting the representative decision-making of citizens and communities in extractive development.
Economic Development	SDG8 – Decent Work and Economic Growth: Mining can develop new economic opportunities for citizens and members of local communities. Providing training, working, and developing business relating to mining activities, associated service providers, or new local economies linked to the mine.
	SDG9 – Infrastructure, Innovation and Industrialization, and SDG12 – Responsible Consumption and Production: Mining can encourage economic development through direct and indirect economic linkages. Developing new infrastructure for transport, communications, water, and energy. Mining can also provide critical materials for renewable technologies and the opportunity for companies to collaborate across the supply chain to minimize waste and to encourage reuse and recycle.

2.3. Methods

The framework to stimulate a strategy to achieve a balancing of economic, environmental, and social requires a systems approach through; Stakeholders and key sustainability issues identification; Programme's development and actions needed to address the main issues; Sustainability indicators developed to measure and monitor performance; result evaluation to sustain continuous improvements based on the triple bottom line and; share information and communication with all stakeholders [14]. Furthermore, the assessment procedures including a detailed description of the mining geosite, assessment of the mining geosite, and management measures should be applied for the study area [15].

Lastly, the land suitability analysis will use spatial multi criteria evaluation that combination between geographic information systems and multi criteria evaluation. The framework of the study is shown in Figure 3 [16]:

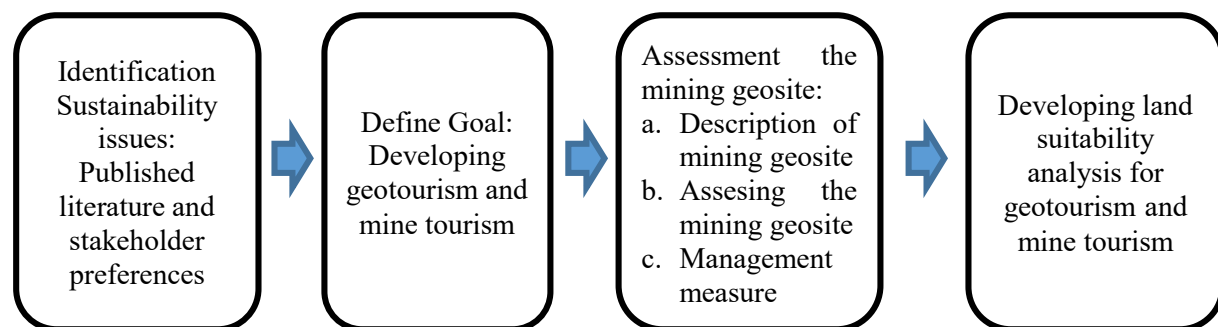


Figure 3. Research framework.

3. Results and Discussion

Achieving sustainable development for mining industries is very challenging. The industry must have engagement in partnership and dialogue with other industry stakeholders from government, civil society to local communities. With the full potential for contributing to the achievement of sustainable development goals, mining companies must work to integrate changes into their core business, with all units of the mining industry, encourage collaboration, partnership, and meaningful dialogue with all stakeholders [13].

The first step is to define key stakeholders for CKA, the selection is based on literature review and discussion with the expert, the stakeholders categorizing as follows; central government agencies, local government agencies, universities or researchers, companies, and communities.

3.1. Stakeholder analysis

There are different stakeholder's preferences on sustainability issues for the Citatah karst area. The preferences are divided into two classes; high interest and low interest (Table 3).

Table 3. Stakeholders' preferences on sustainability issues adapted from [14].

Stakeholder	Sustainability issues		
	Economic	Environmental	Social
Central Government:			
• Geological Agency, Ministry of Energy and Mineral Resources	++	++	+
• Ministry of Environmental	+	++	+
• Directorate General of spatial planning, Ministry of Public Work	+	++	+
Local Government:			
• Archeology Agency, Bandung	+	++	++
• Energy and Mineral Resources Service, West Java Province	++	++	+
• Environmental Management Agency, West Java Province	+	++	+
• Development Planning of West Java Province	++	++	++
• Department of Development and Irrigation, West Bandung Regency	++	++	+
• Environmental Office, West Bandung Regency	++	++	++
• Agency of Development Planning, West Bandung Regency	++	++	++
Universities/Research:			
• ITB	++	++	+
• UNPAD	++	++	++
• Research Group of Bandung Basin	+	++	+
Company:			
• Association of Citatah Miners	++	+	+
• Public Company of Forestry of South Bandung	++	+	+
Communities:			
• Culture Institution of West Bandung	+	+	++
• Tourism Aware Community	++	++	++

++ : High interest, + : Low interest

3.2. Sustainability issues

3.2.1. Economic issues. Mining can contribute to local economic development and economic growth. It can be forced to build new infrastructure, new technologies, and workforce opportunities. Recently, there are several locations of a mining site in CKA. Mining has been started even since the colonial era to mine limestone, marble, andesite, and sand. Mining can provide job opportunities for the surrounding

area. Based on a gross domestic regional product at current market price from mining quarry is about 488,242,800,000 rupiahs or 1.11% of the total in 2018 [17]. The big three economic resources in the West Bandung Regency include processing industries, agriculture, and small and big retails.

To maximize economic benefit for CKA, the government has a plan to boost not only mineral resources but also other resources such as landscape resources, land resources, and cultural resources. CKA has a great attraction not only for tourists but also for sports such as wall climbing.

3.2.2. Environmental issues. Mining operations can cause impacts not only on land, water, and the climate but also on the ecosystem and people that depend on these resources. Based on government regulation No. 26/2008 (No.13/2017) about National Spatial Plan, the Bandung basin is a strategic region in national contexts, because the urban areas of Bandung basin have an important role at the national level for environmental protection and urban development, on article 53 (b) the uniqueness of karst landform is part of geological conservation, as an important part of national conservation.

As a consequence, there is a regulation from the provincial government of West Java No. 22/2010 about spatial planning of West Java province from 2009 to 2029 talking about protection of the CKA. It is followed by regulation from West Bandung Regency about spatial planning of West Bandung Regency from 2009 to 2029 and regulation of west Bandung mayor No. 7/2010 about the protection of Pawon cave site and surrounding area. Lastly, a master plan of the CKA in 2010 was published by the agency of environmental protection management of west Java province.

3.2.3. Social issues. Mining can bring economic opportunities to local communities, on the other hand, challenges to livelihoods and human rights. Administratively, the West Bandung Regency is separated from the Bandung Regency so there is more consent on economic opportunities. In mining areas, there are health and safety issues because of the pollution of mining quarries for example dust and noise. The social conflict also is rising since many stakeholders consider that mining is changing the landscapes. Some groups of people foresee that mining is no longer suitable for the future of the West Bandung Regency. However, in fact, almost 70 percent of Cipatat district employees work in mining industries. The population of the Cipatat district is 134,541 in 2018 or 7,79% of the total population of West Bandung Regency [17]. The future strategy plan to combine geotourism and mining-based tourism hopes will provide more job opportunities.

3.3. Sustainability indicator

The purpose of sustainability indicators for the industry is to help measure a mining company's economic, environmental and social performance and to provide information on how it contributes to sustainable development [12]. The sustainability indicators must be able to change both internally relevant and externally important sustainability issues into representative measures of performance.

The economic indicator is an important issue on how to maximize economic impact not only from mining but also from other economic sectors such as geotourism. For example, to develop backward industries linkages and forward industries linkages of mining industries. Mining industries also can contribute to community development. For example, develop geotourism spots and geotourism infrastructures. The operation of mining in karst, in many cases, can reveal the caves below the ground. The contribution is also to deal with social issues, such as unemployment issues. The important indicator for the environmental aspect is the water quality and pollution index, to achieve an indicator some studies such as spatial analysis is needed to understand the factor that affects the quality of water [18]. The other important environmental indicator is related to a new development of infrastructures; roads, bridges, and dikes must be planned carefully especially when subsidence occurs to prevent damage to vehicles [19]. On the other hand, the planning development of infrastructures has not outweighed the benefits of the karst area and its environmental role, so a sustainable development strategy is needed [20].

It is necessary to present to stakeholders the information on economic, environmental, and social performance in a disaggregated form. The combination of two or more indicators into one measure of

performance to inter-relate different aspects of sustainability is useful because the number of indicators will be reduced. Furthermore, the holistic concept of sustainable development should consider all three pillars of sustainability simultaneously. In practice this may be difficult to reach, integrated indicators could bring us a step closer to achieving sustainability goals [12].

3.4. Assessment procedure of geotourism and mining tourism

The assessment procedures including a detailed description of the mining geosite, assessment of the mining geosite, and management measures should be applied for the study area.

3.4.1. *Description of mining geosite.* Many authors have proposed to describe the mining geosites [5,15,21]. The authors proposed potential geotourism as follows in Table 4.

Table 4. Aspect and attribute for describing potential geotourism of mining geosite adapted from [5,15,21].

Aspect	Attributes
1. General information	<ul style="list-style-type: none"> Name: Marble, limestone, and andesite/sand quarry project (combined) at CKA
2. Geological settings	<ul style="list-style-type: none"> Location: Cipatat District, West Bandung Regency Geological unit: The only non-volcanic products located in the west part of Bandung Basin, namely Rajamandala formation which consist of limestones, clay, marl, and quartz sandstone, and the oldest formation in the Bandung basin (Oligocene age)
3. Geomorphological setting	<ul style="list-style-type: none"> Main landform: Quarry mining landform, mining activities create artificial hills and valleys and also massive undulation. Process: There are about 43 mining companies with three different statuses: active, non-active mining, and extension production. The extraction and overburden removal are used by shovel and dumper. Slope and aspect: The elevation area from 209 to 975 masl. The slope of the area is mostly (80%) more than 15%. The sunny slope has an aspect of about 22,5^o -157^o.
4. Ecological characteristics	<ul style="list-style-type: none"> Description of the ecosystem: The area has more than 50 potential medicinal plants for example local plants called <i>singa depa</i>. Based on land characteristics, the suitable plants for the reclamation program are guava, maize, and albasia.
5. Hydrological and hydrogeological features	<ul style="list-style-type: none"> Water bodies: The area belongs to the Cimeta watershed as part of the Citarum watershed. Ciburuy lake is one of the famous tourist destinations. Citarum river is located in the western part of CKA.
6. Historical and cultural characteristic	<ul style="list-style-type: none"> Geohistorical importance: There are many big caves as living spaces for the oldest humankind in West Java. Cultural composition: The area is dominated by Sundanese ethnic
7. Land use and status	<ul style="list-style-type: none"> Administrative: The total area is about 12,199 hectares, mining occupied area is about 349 hectares belonging to the Cipatat district, West Bandung Regency. Land status or ownership: Land belongs to private, industry, and government.
8. Scientific aspect	<ul style="list-style-type: none"> The rarity of the site: The oldest karst area and the prominent archaeology site in west Java. Academic importance: The field study area for students from ITB, UNPAD, and others.
9. Population	<ul style="list-style-type: none"> Population density: from 1.26 to 98 people per square km
10. Current use	<ul style="list-style-type: none"> Current activity: mining industry, settlement, agriculture, plantation, tourist area, and forestry.

Table 4 are data compiled from [2,8–10,22] and other primary resources. From Table 4, it can be concluded that the general description of mining geosite at CKA has the potential to combine between mining and geotourism.

3.4.2. *Assessment of mining geosite.* Many authors have proposed to assess the mining geosites [5,15,21]. The authors proposed potential geotourism as shows in Table 5.

Table 5. Criteria for assessment of mining geosite potential [5,15,21].

Criteria	Assessment	Remarks
1. Geotourist attraction: Are there any geotourism attractions present?	Many numbers of attractions	There are existing geology-based tourisms in or close to CKA such as stone garden, Ciburuy lake and extreme sports such as rock climbing, orienteering, caving, and water sports rafting in Citarum river and Ciburuy lake. And additionally potential mining geosites such as: <ul style="list-style-type: none"> • Mining landscape • Processing plants • Reclamation areas • Artificial hills and valleys • Opening caves • Mining roads • Fossils
2. Geosite accessibility: is the site accessible?	Accessible without any problem	The site is located close to the national road, and the toll road, the nearest railway station is Padalarang station, and the nearest airport is Husein Sastranegara Airport, Bandung.
3. Safety levels: Are there any phenomena that can endanger the visitor?	Some specific limitations	The active mining operating mining machinery, mining hauling, and probably blasting.
4. Tourist facilities: Are there any tourist facilities?	There are tourist facilities	CKA is close to the new city of Parahyangan with MICE facilities and a shopping center.
5. Viewpoint and visibility of the site: Are there any viewpoints from which the site can be observed?	Many viewpoints	From the highest elevation, viewpoints were seen.
6. Tour guide availability: Is a tour guide available?	Tour guide available	There is a tourism awareness group (locally called as POKDARWIS)

From the assessment from table 5, all aspects including attractions, accessibilities, facilities, viewpoints, and tour guides have high points. It can be concluded that CKA has the potential to be a mining geostation tourism area, except for the safety level that should be careful since there are active mining operations.

3.5. *Geotourism tourism suitability analysis*

After the assessment procedures including a detailed database of the mining geosite, assessment of the mining geosite, and management measures applied for CKA, then evaluation of the land suitability of karst landform and other limestones formation in the CKA for geotourism using spatial multi criteria evaluation, the final study result is how to manage karst area in sustainable manners based on social

criteria, environmental criteria, and economic criteria. Sensitivity analysis will be applied to see how to make the balance between the three criteria.

4. Conclusions

The mining and minerals industry has the main challenge for addressing environmental, social, and economical sustainability. The sector is needed to demonstrate that mining can contribute to the welfare and wellbeing of the current generation in their mining areas, and of course without compromising the potential of future generations for a better quality of life. The framework to stimulate a strategy to achieve sustainable development through Stakeholders and key sustainability issues identification; Programme's development and actions are needed to address these issues; sustainability indicators development to enable performance measuring and monitoring; progress evaluation to sustain continuous improvements of the triple bottom line; and Information sharing and communication with stakeholders. To combine geotourism and mining tourism, the assessment procedures including a detailed description of the mining geosite, assessment of the mining geosite, and management measures should be applied for the study area. The appropriate analysis method is spatial multi criteria evaluation as a combination of geographic information systems and multi criteria evaluation. Geotourism at mining sites is getting attention from all stakeholders in the CKA, as one solution for the preservation of mining-geoh heritage. From the rapid assessment procedure, we can conclude that CKA has the potential to be mining geosite tourism areas. However, safety should be prioritized since there are active mining operations.

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