Indonesian Journal of Electrical Engineering and Computer Science
Vol. 38, No. 2, May 2025, pp. 904~914
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v38.i2.pp904-914

Geographic information system-based approaches for evaluating CO_2 storage in Kalimantan basins, Indonesia

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Article Info

Article history:

Received May 14, 2024
Revised Oct 24, 2024
Accepted Nov 10, 2024

Keywords:

Basin
Geographic information system
Scoring
Screening
Weighting

ABSTRACT

To achieve the energy transition towards more environmentally friendly energy, various approaches must be taken, one of which is CO_2 source-to-sink matching. A basin evaluation study has been carried out through classifying, weighting, and scoring in the geographic information system (GIS) for screening and ranking basins for CO_2 storage on the island of Kalimantan, Indonesia. The region covers 13 sedimentary basins that have the potential to serve as CO_2 sinks. As many as 21 parameters have been analyzed through classification and weighting using a pairwise comparison matrix method to produce scores and ranks for each basin. The results show that the Kutai, Tarakan, and Barito basins are the top three basins for CO_2 storage potential. Singkawang, Nangapinoh, Pangkalanbun Utara, and Embaluh Selatan basins have been found to have the lowest sink potential.

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1. INTRODUCTION

Indonesia produced CO_2 emissions of around 728.9 million metric tons (MT) in 2022, or an increase of around twenty-fold compared to 1970, which was only 35.8 MT [1]. This is largely due to the increasing use of fossil energy to meet the high demand for energy in this country [2]. It is expected that Indonesia can contribute to global subsurface CO_2 storage of around 1–30 billion MT ($GtCO_2$) in 2050 along with the United States (60%), China, and other countries [2]. The CO_2 emission reduction scenario is carried out by reducing the use of fossil energy and transitioning through the use of new and renewable energy of around 26% in 2050 [3]. Another effort made is through CO_2 capture and storage (CCS) in subsurface formations, as has been done in many countries [3] in which the CO_2 can be stored in coal seams, saline aquifers, geothermal, and oil and gas fields in enhanced oil/gas recovery (carbon capture usage and storage/CCUS) scheme, geothermal, and others [4]–[6]. The use of CCS/CCUS technology facilitates the process of energy transition to new renewable energy gradually, where fossil energy sources can still be utilized while emitted CO_2 is captured and stored in such geological formations.

CCS/CCUS activities in Indonesia are still in their early stages, albeit studies have been intensively carried out since 2015. Examples are the CCS/CCUS project at Merbau gas collection station (South Sumatera), where the captured CO_2 is to be injected into the surrounding oil and gas fields [3], the CCUS project in Sukowati oil field, Tuban, East Java [7], and the CCUS project in Gundih gas field in Central Java [8]. The latter has proceeded into demonstration stage. Obstacles that are faced in such applications of CCS/CCUS are the increasing cost of electricity generation, location-related constraints, CO_2 storage capacity, CO_2 transportation, level of security in geological terms, potential leakage problems, and community acceptance [3]. Despite constraints, these kinds of studies and activities must proceed. Past studies have shown promising depictions. For instance, a study on CCS/CCUS in the Northwest Java basin over CO_2 injections into depleted fields has seen the prospect of storing 287.50–834,955 million tons of CO_2 [9].

The focus area in this study is the Kalimantan region of the Republic of Indonesia, upon which the new Indonesian state capital city (Ibu Kota Nusantara, IKN) is currently under construction shown in Figure 1. As a new capital based on the premises of a "smart, green, beautiful, and sustainable city" it needs the support of various data to make it easier to plan developments. Moreover, fossil energy is still the main energy source in the Kalimantan region, highlighting the necessity of establishing CCS/CCUS programs for the existing power plants and industries, hence securing the new city's energy and environmental basic principles. This condition could be implemented with an integrated system that includes installing CO_2 capture devices at emission sources in power generation and industrial plants, and then transporting and storing the captured CO_2 in geological formations according to feasible CCS/CCUS programs. Sufficient energy supply is reported to be needed in the future to support further development of the city. An estimated 3.75 gigawatts (GW) of electrical energy is needed, or an additional 3.04 gigawatts over the existing electrical energy capacity [10].

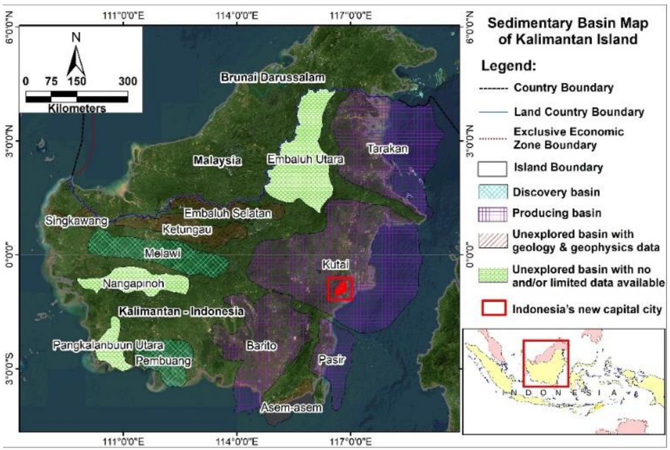


Figure 1. Sedimentary basins in Kalimantan Island with their categories. The map also depicts the location of Indonesia's new capital city

Geographic information system (GIS) technology is essentially used to facilitate understanding complex situations with real and geographically oriented solutions. This system makes it easier to assess, plan, and implement all expected results [11]. GIS in various studies proves its importance due to its ability to analyze spatial-based data so that it can be used for various applications, such as nutrition program interventions and for monitoring their success [12]; analyzing electromagnetic pollution produced by non-ionizing radiation (NIR) sources in a city [13]; and informing the availability of renewable energy sources and assisting the decision-making process for achieving a diverse and sustainable territorial energy matrix [14]. In this study, GIS is used for basin assessment in the region under study, Kalimantan - Indonesia. This study is part of a study on mapping CO_2 sources and storages in Indonesia that has previously been carried out mainly on the islands of Java and Sumatra. This study was performed with a set of aims focused on classifying, weighting, and scoring with the help of GIS in Kalimantan's basins in terms of geology, safety, infrastructure, and CO_2 sources, which were then used for basin ranking. The parameters in each of these basins were then be used to determine the reliability of basins for CO_2 storage, ensure their safety from potential leaks, optimize operational plans, monitor purposes, and economics evaluate economics [5], [15], [16]. The primary output of this study is the identification of the priority basins in the Kalimantan Island for CCS/CCUS implementation.

2. METHOD

Screening and ranking of Kalimantan's basins used various parameters in the GIS shown in Table 1. The stages carried out for screening and ranking include: i) collecting data or parameters. These parameters were obtained from various authorized agencies and published papers, as shown in Table 1; ii) Registering a raster map to a geographic longitude-latitude position and digitizing or inputting attributes into basin data; iii) Overlaying all parameters used a GIS with Kalimantan's sedimentary basins to identify the classes of each parameter. This includes setting up an assessment table into five classes for each parameter/criterion where the highest class is occupied by the most suitable, whereas the lowest class is occupied by the least suitable. The class of each parameter shows that the higher the value, the more suitable the parameter is for the CCS/CCUS program (Table 2). Compilation was then made in a table of assessment results for all parameters/criteria for each sedimentary basin in the study area; iv) Analyzing the weight of each parameter using the pairwise comparison method (Table 3). This process assigns a score to each parameter based on its importance, distinguishing those with greater influence or priority in the analysis, or ranking them by their significance; v) Multiplying each parameter by its weight. This helps determine the relative importance of each parameter, as not all parameters have the same influence; vi) Summing all multiplication results between parameters and weights so that the total value of each basin can be identified; and vii) Ranking the basin by its score or value. The highest value corresponds to the best ranking indicating the main priority basin(s). Flow chart of the study's activities is presented in Figure 2.

Table 1. Parameter used for basin evaluation through screening and ranking

Parameter	Sources data	Parameter	Sources data
Tectonic setting	Geological Agency - MEMR	Trap development	LAPI ITB - SKK Migas (2008)
Basin location and/or water depth	Geological Agency - MEMR, Bathymetry Data (Topex)	Seismicity	National seismic hazard maps of Indonesia [17]
Basin size	Geological Agency	Fault & fracture intensity	SRTM (USGS), Bathymetry Data (Geological Agency – MEMR)
Basement depth	Beicip-PPPTMGB LEMIGAS, LAPI ITB - SKK Migas (2008)	Gradient geothermal	NGDC, Indonesian Petroleum Association, and SEAPEX.
Sediment thickness	Pertamina-Unocal (1997), Darman & Yuilong (2020)	Reservoirs temperature	NGDC, Indonesian Petroleum Association, and SEAPEX, Indonesian Petroleum Association, LAPI ITB - SKK Migas (2008), Previous Study
Reservoirs Depth	NGDC, Indonesian Petroleum Association, and SEAPEX	Hydrology	Geological Agency - MEMR, Kementerian PUPR
Reservoirs thickness	NGDC, Indonesian Petroleum Association, and SEAPEX.	Basin maturity	Geological Agency - MEMR
Reservoirs porosity	Indonesian Petroleum Association, LAPI ITB - SKK Migas (2008), Previous Study	Earthquake	Geological Agency - MEMR, USGS website
Permeability	Indonesian Petroleum Association	Volcanism	Geological Agency - MEMR
Number of seals	Indonesian Petroleum Association, LAPI ITB - SKK Migas (2008), Previous Study	Sources of CO_2	The National Electricity Company (PLN)
		Infrastructure of Oil and Gas	PPPTMGB "LEMIGAS" Database

The parameters used include those related to potential CO_2 leaks such as seismicity, volcanism, faults, and fractures; parameters of CO_2 emission sources, especially power plants and petroleum refineries; presence of depleted oil and gas fields; potential saline aquifer/formation; and other information and properties for each basin. Information about a sedimentary basin includes basin area, geological factors such as saline formation thickness, environmental conditions, existing infrastructure for logistical considerations, distances, and geographical features around the CO_2 sources and sinks [16], [18]–[21]. This data has been obtained from government agencies, scientific publications, and research institutions in Indonesia. The assessment of each parameter is carried out by considering parameters of safety, economics, environment, CO_2 storage capacity (basin area and distribution), and logistics [16], [19]–[21]. The tectonic setting on the passive margin that characterizes the Kalimantan region is generally safer due to its stable tectonics and absence of active volcanoes and large earthquakes [22]. The depth of saline formation increases the capacity of CO_2 storage capabilities as CO_2 density increases with depth [16], [20], [23]. Volcanic activity and seismicity are important considerations in basin screening for CO_2 storage, considering that Indonesia is located on the ring of fire in the volcano line and four major world tectonic plates. In this condition, earthquakes, tsunamis, and volcanic eruptions are of frequent occurrence [24], [25]. Referring to these conditions, an assessment of each parameter is prepared and considered, with modifications made and adjusted in accordance with Indonesia's geological conditions shown in Table 2.

Table 2. Classification-of each parameter to analyze of the sedimentary basin of Kalimantan Island

Parameter/class	1	2	3	4	5
Tectonic setting (TS)	Fore Arc, trench/ convergence	Transtensional (strike-slip) intermontance, oceanic, marginal oceanic (cratonic)	Rifting valley (intermontance-cratonic) and rifting valley (fore arc-cratonic convergence), foreland	Passive margin deltaic cratonic and foreland cratonic convergence, rifting valley back arc and foreland cratonic convergence, back arc convergence	Passive margine cratonic, Passive margin rifting valley cratonic, rifting valley cratonic, rifting valley passive margin cratonic
Basin location - on/off-shore (BL)	Offshore (>500 m)	Offshore (<500 m)	Onshore-Offshore (>100 m)	Onshore -Offshore (<100 m)	Onshore
Basin size - sq. km (BS)	<30,650	30.650-55,750	55,750-80,800	80,800-105,800	>105,800
Basement depth -MSL (BD)	1000-2000	2000 - 3000	3000-4000	4000-5000	>5000
Sediment thickness-m (ST)	1000-<2000	2000 - <3000	3000-<4000	4000 - <5000	>=5000
Reservoir depth-m (RD)	<1000	2000 - 2500 with 1 or without reservoirs data	2000-2500 with 2-3 reservoirs data	2000 - 2500 with 4 - 5 reservoirs data	2000 - 2500 with >5 reservoirs data
Reservoir thickness (m)	No Data	0-50	50-100	100-150	>150
Reservoir porosity-% (RP)	No Data	<10.7	10.7-15.4	15.4-20.1	>20.1
Seal (S)	No Data	No data of thickness, Number of Seals formation is 1	No data of thickness, Number of Seals formation is 2	No data of thickness, Number of Seals formation is 3	No data of thickness, Number of Seals formation are =>4
Seismicity max -pga (Se)	>0.5	0.4-0.5	0.3-0.4	0.2-0.3	0.1-0.2
Fault and fracture intensity (FFI)	>.4.211	3.21-4.211	2.140-3.21	1.07-2.140	<1.07
Geothermal gradient °C/km (GG)	>5	4-5	3-4	2-3	<2
Volcanism -km (V)	<50	50-100	100-150	150-200	>200
Hydrology (H)	Offshore	Dominant offshore and basins with lov water productivity (scarce of groundwater) and groundwater basins with low continuity and groundwater can be obtained wi small discharge	groundwater basin (aquifers) with local productivity	Groundwater basin with moderate aquifer productivity	High productivity groundwater basin with wide distribution
Earthquake Magnitude (EM)	5->8	4-8	4-7	4-5	<4
Basin maturity	Basin with no/limited data availability	Unexplored basin with geology and seismic data	Prospect basin	Discovery basin	Producing basin
Reservoirs temperature -°C (RTe)	75-200	35-200	35-150	35 - 100	35-75
Permeability (P)	No Data	0.1-100	100-150	150-200	>200
Sources of CO_2 (SCO_2)	No Data	1-3	4-10	10-15	>15
Trap development (TD)	No Data		Stratigraphic or, structural, or limestone build-up	structural and Stratigraphic	structural and Stratigraphic, combined of both and also limestone
Infrastructure of oil and gas (IOG)	No Data			<5 wells	>5 wells

Table 3. A pairwise comparison matrix used for the weighting analysis of each parameter

No	Parameters	TS	BL	BS	BD	ST	RD	RTh	RP	S	Se	FFI	GG	V	Hy	EM	BM	SCO_2	Pe	IOG	RTe	TD	TV	W
1	TS		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20	0.035
2	BL	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20	0.035
3	BS	2	2		1	1	1	1	1	1	2	2	2	2	2	2	1	1	2	2	1	2	31	0.054
4	BD	2	3	1		1	1	1	1	1	2	2	2	2	2	2	1	1	2	2	1	2	32	0.056
5	ST	2	3	1	1		1	1	1	1	3	3	2	2	3	2	1	1	2	2	1	2	35	0.061
6	RD	3	3	3	3	3		1	1	1	3	2	3	3	3	2	1	1	2	2	1	2	43	0.075
7	RTh	3	3	2	2	2	1		1	1	3	2	2	2	2	2	1	1	2	2	1	2	37	0.065
8	RP	3	2	2	3	3	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	28	0.049
9	S	3	2	2	2	3	3	3	3		1	1	1	1	1	1	1	1	1	1	1	1	33	0.058
10	Se	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	20	0.035
11	FFI	1	1	1	1	3	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	22	0.038
12	GG	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	20	0.035
13	V	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	20	0.035
14	Hy	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	20	0.035
15	EM	1	1	1	1	1	1	1	1	1	1	2	1	1	1		1	1	1	1	1	1	21	0.037
16	BM	3	3	2	1	1	1	1	1	1	3	3	3	3	3	3		1	2	2	2	2	41	0.072
17	SCO_2	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1		1	1	1	1	21	0.037
18	Pe	2	2	1	1	1	1	1	1	1	2	2	2	2	3	2	1	1		2	1	2	31	0.054
19	IOG	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1		1	1	23	0.040
20	RTe	2	2	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	2	2		2	31	0.054
21	TD	2	2	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1		24	0.042
	Total	32	32	24	24	27	20	20	20	18	29	28	27	28	30	26	19	19	24	25	20	26	573	1.000

Note: TS = tectonics setting. BL = basin location. BS = basin size. BD = basement depth. ST = sediment thickness. RD = reservoirs depth. RTh = reservoirs thickness. S = seal. Se = seismicity. FFI = fault & fracture intensity. GG = gradient geothermal. V = volcanology. H = hydrology. EM = earthquake magnitude. BM = basin maturity. SCO_2 = sources of CO_2. Pe = permeability. IOG = infrastructure oil & gas. RTe = reservoirs temperature. TD = trap development. TV = total values. W = weight.

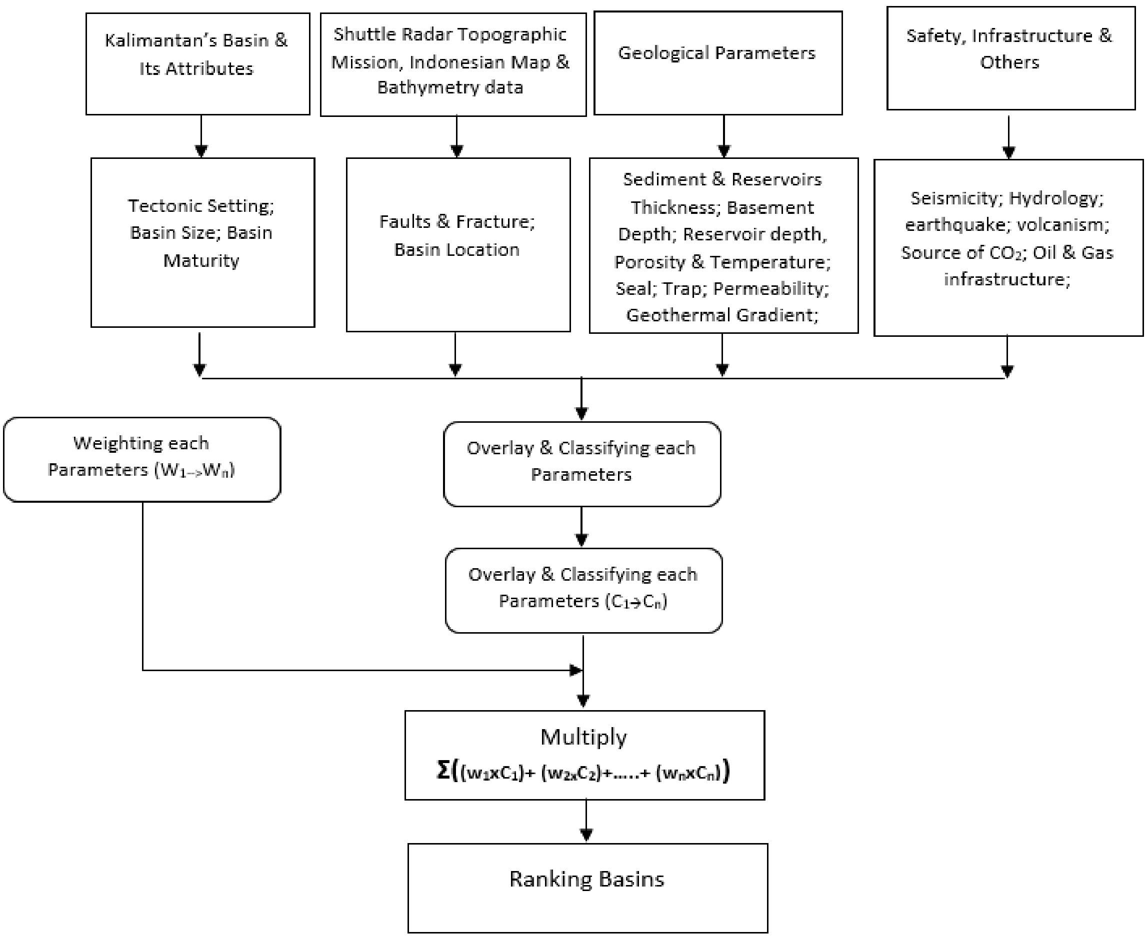
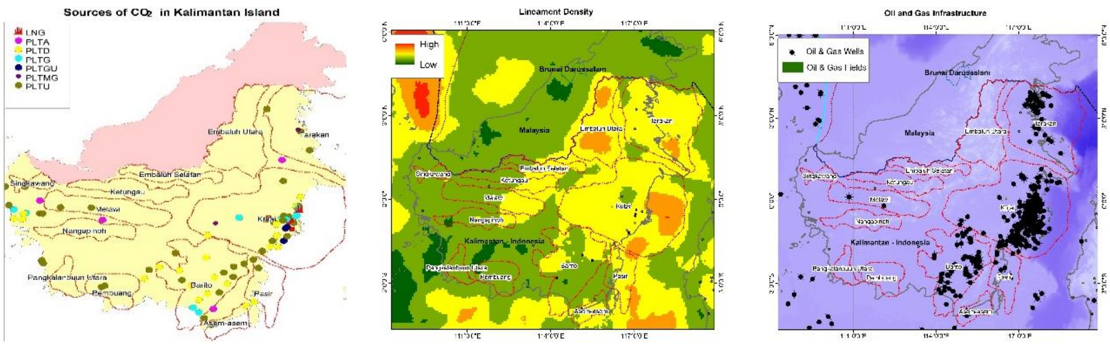


Figure 2. Workflow of basin evaluation for CCS/CCUS in Kalimantan Island through screening and ranking based on the GIS

Registration is performed on a map that is not yet geographically oriented using GIS software to input coordinates on the map based on their corresponding coordinates on the earth, using a reference map. Digitization is the process of converting analog data into digital format. Attribute input is conducted by entering information according to its location on the digital map. The parameter class for each basin as shown in Figure 3 was identified by overlaying the parameters used, such as CO2 source (Figure 3a), lineament density (Figure 3b) and oil and gas infrastructure (Figure 3c) with the basins in Kalimantan.



a b c

Figure 3. Map overlay of sample parameters for classifying each basin: (a) Overlapping of CO_2 sources with basin, (b) Overlapping lineament density with basin, and (c) overlapping of oil and gas infrastructure with Basin

Weighting is carried out to determine the priority i.e. importance of each parameter in the screening process and basin ranking for CCS [21]. The weighting method is carried out using the pairwise comparison matrix method. The weighting used to propose the model for each parameter has a score of between one and three. A score of 1 indicates that each parameter has equal value in importance; a score of 2 indicates that the criteria in row mode are slightly more important than the criteria in column mode, whereas a score of 3 indicates that the criteria in row mode are more important than the criteria in column mode [19]. Upon analyzing all parameters in this manner, the scores are summed up on each line. The weight of each criterion is the sum of scores in one row divided by the total scores of all criteria. The pairwise comparison matrix used in weighting is presented in Table 3.

Scoring for each basin is done by multiplication between the weight of each parameter and the class value of each basin. The results are then summed to produce values that represent the rank of the basins. There is no normalization of scores between the range of 0 and 1 in the basin ranking process. This is because all parameters have been assessed using weights to represent the relative relevance of factors to storing CO_2. Basin(s) with the highest total values are the best candidates for CCS programs, while basins with the lowest total values are the less suitable candidates for the CCS schemes.

3. RESULTS AND DISCUSSION

An overlay of 21 parameters with 13 basins on Kalimantan Island has been performed, and the results show a class that reflects the condition of each basin relative to the parameters aligned in the same geographical area (Table 4). The higher the class value for each basin's parameter, the more favorable the conditions for the CCS/CCUS target. The results are then multiplied by the weight of each parameter presented in Table 3, and the values are summed to generate a score for each basin (Table 5).

The calculation results show that the top three basins are Kutai, Tarakan, and Barito basins, with scores of 4.11, 3.98, and 3.94, respectively (Table 5). Those three basins are hydrocarbon-producing basins. However, it is worth noting that the results of this regional and qualitative study need to be enhanced further with a detailed study on the best three basins supported by more accurate and massive data so that detailed locations and CO_2 storage capacity can be known for the assessment of the project's economics. On the other hand, the basins with the lowest scores are Singkawang, Nangapinoh, Pangkalanbuun Utara, and Embaluh, Selatan with values of 2.23, 2.15, 2.14, and 2.12, respectively. The four sedimentary basins are characterized by sediment thicknesses of less than 1,000 m [26].

Kutai Basin, the best basin for CCS/CCUS, is a prolific hydrocarbon-producing basin with a tectonic setting of a passive margin-deltaic system, which has an area of about 130,970 km^2 [27]. This basin is located in the eastern part of Kalimantan island, with its depocenter having depths deeper than 15,000 meters [26]. Kutai basin is a Cenozoic sedimentary basin, with outcrops of Paleogene rocks and older rocks located on the western edge of the basin, but access to these locations is difficult [28]. Based on seismic hazard map data, Kutai basin has the highest peak ground acceleration (PGA) of around 0.3g, where if there is an earth quake it can reach the VII modified mercalli scale (MMI), in which vibration is felt strongly, and therefore has the potential for moderate structural damages leading to category of moderate to heavy level of vulnerability [17], [29]. Nevertheless, Kutai Basin is also regarded as the centre of many government-driven activities, where industry and other sectors are growing rapidly. In this basin, the new Indonesian capital city is located.

Table 4. The class for all sedimentary basins based on overlay analysis over the 21 parameters

		Parameter																				
No.	Basin	TS	BL	BS	BD	ST	RD	RTh	RP	S	Se	FFI	GG	V	Hy	EM	BM	SCO_2	Pe	IOG	RTe	TD
1	Asem-asem	4	4	1	3	3	2	1	1	1	5	3	3	5	1	4	3	2	1	4	3	3
2	Barito	4	4	3	4	4	3	5	5	2	4	4	3	5	3	4	5	5	5	5	3	3
3	Embaluh Selatan	1	5	1	1	1	2	1	1	1	5	3	3	5	1	5	3	1	1	1	3	3
4	Embaluh Utara	1	5	2	3	4	2	1	1	1	5	2	3	5	1	5	2	1	1	1	3	3
5	Ketungau	4	5	1	2	3	1	1	4	2	5	4	2	5	1	5	3	1	1	1	3	3
6	Kutai	4	3	5	5	5	5	4	5	2	3	3	3	4	3	3	5	5	5	5	3	4
7	Melawi	4	5	1	2	3	4	1	4	2	5	4	2	5	1	5	4	2	1	4	3	3
8	Nangapinoh	5	5	1	1	1	1	1	1	1	5	4	3	5	1	5	2	1	1	1	3	3
9	Pangkalanbuun Utara	4	5	1	1	1	1	1	1	1	5	4	2	5	1	5	2	1	1	1	4	3
10	Pasir	4	3	1	4	2	3	4	5	2	5	3	3	5	1	4	5	2	1	5	3	3
11	Pembuang	4	4	1	1	2	1	1	1	1	5	5	3	5	1	5	4	2	1	1	4	3
12	Tarakan	4	3	4	5	5	5	4	4	5	3	3	3	4	2	2	5	3	5	5	2	4
13	Singkawang	5	5	1	1	1	2	1	1	1	5	3	1	5	1	5	3	2	1	1	3	3

Table 5. Results of basin ranking

No	Basin	Score
1	Kutai	4.11
2	Tarakan	3.98
3	Barito	3.94
4	Pasir	3.21
5	Melawi	2.99
6	Asem-asem	2.55
7	Ketungau	2.54
8	Pembuang	2.42
9	Embaluh Utara	2.36
10	Singkawang	2.23
11	Nangapinoh	2.15
12	Pangkalanbuun Utara	2.14
13	Embaluh Selatan	2.12

Tarakan Basin is the second-best basin for CCS/CCUS. Results of analyses of seismic hazards indicate that this basin is similar to the Kutai basin. However, in terms of intensity, seismicity is more common in the Tarakan Basin [17]. The PGA values of the Tarakan basin are also relatively high, with the highest being around 0.3g. There have been earthquakes that can reach the VII Modified Mercalli scale (MMI) with strong vibration, have the potential for moderate damage to building structures, and also have a moderate to heavy level of vulnerability ([17], [29].

Barito, Pasir, and Asem-Asem basins, based on evaluation of seismic hazard maps, have the highest PGA values of around 0.25g, with seismicity reaching VI Modified Mercalli scale (MMI), meaning seismic activities in those areas can cause light to moderate damages [17], [29]. The Barito basin, in addition, has a basement depth of about 3,650 meters [30]. Therefore, in general, the Barito, Pasir, and Asem-Asem basins are relatively safe for CCS programs. Other sedimentary basins, the Pembuang, Pangkalanbuun Utara, Singkawang, Ketungau, and Embaluh Selatan, are also regarded as safe from earthquake hazards due to their low lineament density. The maximum PGA value in these basins is around 0.2g. The problem is that the area is narrow, which indicates limited CO_2 storage resources. In addition, the basins are characterized by very limited geological and geophysical data which implies that when they are to taken into studies for their CO_2 storage resources rigorous efforts are needed to secure more data through, among others, geological and geophysical surveys.

Finally, based on the results of this study, GIS-related approaches have proven effective in providing information for decision-making processes, as they can help identify, select, and rank basins in Kalimantan for CCS/CCUS programs. These findings can be used to create a priority scheme for CCS/CCUS initiatives in the Kutai, Tarakan, and Barito basins, the largest basins in Kalimantan region covering wide areas of 115,600 km², 63,050 km², and 41,030 km², respectively. The overall size itself reflects the region's significant CCS – and CCUS – CO_2 storage resources, especially vis-à-vis the rapid economic growth in the region. Additionally, these results also support the IKN program, which aims to develop a 'smart, green, beautiful, and sustainable city,' as well as the targetted national net zero emission (NZE) 2060 goals. It is anticipated that the global trend of CCS/CCUS programs will gain acceleration in the period of between years 2040 and 2060 [31], and Indonesia has the potential to become a CCS/CCUS hub in Southeast Asia, connecting corridors with Singapore and Malaysia, utilizing the North Sumatra, Central Sumatra, and Malay basins for permanent storage [32]. Meanwhile, Kalimantan could also be regarded and prepared as recommended hubs for the corridors for huge economies of China, Japan, and Korea with Indonesia's Central and Eastern regions.

4. CONCLUSION

Based on classification, weighting, and scoring methods using the GIS, Kutai, Tarakan, and Barito basins are the top three best sedimentary basins for CO_2 storage on the island of Kalimantan. Apart from the three basins, the conditions of sedimentary basins in Kalimantan in general are safe for CCS activities. The basins with the lowest ranks of Singkawang, Nangapinoh, Pangkalanbun Utara, and Embaluh Selatan, with their relatively thin sedimentary column thicknesses of less than 1000 m–therefore less favorable for CCS operations - still have the potentials, even though more thorough studies requiring more substantial data in sufficient quantity/quality are needed. Generally, this study concludes that the Kutai, Tarakan, Barito, Pasir, Melawi, Asem-Asem, Ketungau, Pembuang, and Singkawang basins have the potential for CO_2 storage, which can accommodate CO_2 emissions from power and industrial plants in the Kalimantan regions and beyond. These CO_2 storage resources in Kalimantan region can certainly serve as a chain in Indonesia's potential as a regional CCS/CCUS hub.

ACKNOWLEDGEMENTS

We thank the Research Centre for Geoinformatics—Research Organization for Electronics and Informatics—National Research and Innovation Agency (BRIN) and the Research Centre for Process and Manufacturing Industry Technology—Research Organization of Energy and Materials (at BRIN), and the RIIM/LPDP organization for supporting this research. We also thank all those who have helped in preparation of the survey equipment and laboratory instruments for sample analysis during the study and all individuals who assisted this research.

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