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RESEARCH PAPER

Spatial model of industrial area suitability using spatial multi criteria evaluation: A case study in Kendari City

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Abstract. Designing an industrial location must be based on consideration of factors that will influence it such as natural, environmental and ecological conditions. One of the spatial-based location determination methods is Spatial Multi-Criteria Evaluation (SMCE). This study aims to determine suitable industrial areas and compare industrial locations that have been determined based on the Regional Spatial Plan (RTRW) for 2010-2030 in Kendari City. Industrial areas must be flood-free, located in a relatively flat area, far from settlements, have good access and must not interfere with the river's natural function. Therefore, the aspects of access, hydrology, physiography and convenience were all taken into account in this study. The area in Scenario A was retested with Scenario B and Scenario C to get a variety of industrial areas with different perspectives. Kendari City's appropriate industrial area is 2.462.36 ha and is located in Puuwatu Sub-District, which is directly connected to Mandonga Sub-District (scenario 2.C). The RTRW map with the industrial model of the area shows the mismatch of the proposed industrial area placement. The results of this industrial area can be used as an alternative for decision-makers.

Keywords: Spatial Multi Criteria Evaluation; Regional Spatial Plan; Kendari City; Industrial Area.

1. Introduction

Industrial location determination is a critical point in the process of starting, expanding and changing industrial system areas. Determining the critical point will determine whether the specified industrial location can increase profits by reducing production costs and controlling a wider market share without neglecting environmental and ecological aspects (Handoko 2000). Site selection in determining and attaining goals generally involves complex decision-making process that can lead to conflicts. This selection can bring up many possibilities, both beneficial and detrimental to the surrounding area (Gal et al., 2013). These goals are basically complementary or contradictory in planning activities (Carver, 1991; Eastman et al., 1998; Eldrandaly et al., 2003; Gal et al., 2013; Zavadskas et al., 2014).

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In fact, 80% of the data used in regional planning by managers and decision-making is more geographic/spatial (Worral, 1991; Gal et al., 2013), which is known as geographic or spatial decision problems (Malczewski, 2004). Planning in various disciplines gives rise to terminology, such as from the fields of economic, environmental, social, urban, regional and others. Development planning, which has been incorporated into the National Development Planning System (Law No. 25 of 2004), and Spatial Planning, which is contained in the Spatial Planning System (Law No. 26 of 2007), are the legalized planning processes in Indonesia (Dewi et al., 2009).

Planning and problem-solving often utilizes information and communication technology to exchange ideas and information in overcoming problems in the future (Effat, 2014; Alavi & Sabagh, 2017). Problems in spatial planning often require alternatives to be evaluated based on several criteria whose decision making involves several alternatives with more than one criterion and choosing one alternative with many criteria where the main input is human perception (Chakhar & Mousseau, 2008; Gal et al., 2013).

Geographic information system (GIS) is a technology that performs spatial analysis by providing functionality in capturing, storing, querying, analyzing, displaying and issuing geographic information (Rikalovic et al., 2014; Wang et al., 2019). The development of GIS in the planning field has led to a sharp increase in analyzing locations based on attribute data, especially in the Multi-Criteria and Multi-Objective site analysis procedures (Sánchez-Lozano et al., 2013; Rikalovic et al., 2014; Ruiz et al., 2020). Emphasis can be placed on subjective influence, discrepancies in evidence and decisions, evidence of aggregation in the degree of trade-off between criteria and the likelihood of conflict avoidance in objective decision-making in multiples (Eastman et al., 1998). The development of GIS in carrying out planning requires Spatial Decision Support System (SDSS) tools to support users or groups of users in achieving higher effectiveness from decision makers while solving semi-structured spatial decision problems because of their interactive nature (Malczewski, 1997; Maleki et al. al., 2018). This system can run well if it is supported by basic spatial data as input, good data storage including place/hard disk/server management, good analysis and human resources with strong spatial awareness.

One of the supporting analyses for SDSS is Spatial Multi-Criteria Evaluation (SMCE). Making a selection from several alternatives or criteria is the first step in applying SMCE to a specific area. Furthermore, standardization criteria and weights are assigned to each criterion in order to produce a map. This map displays the suitable areas by showing different area choices that are helpful in decision-making (Raaijimakers, 2006; Gal. et al., 2013; Etxano & Villalba-Eguiluz, 2021; Aldiansyah & Wibowo, 2022; Arimjaya et al., 2022). GIS software such as IDRISI, ILWIS and ArcGIS has integrated the Multi-Criteria Analysis (MCA) application into their spatial processing database. ArcGIS was developed by the Environmental Systems Research Institute (ESRI) with more dynamic data management, plugin variations on vector and raster data (Graser et al., 2017; Wegmann et al., 2020), strong geostatistical analysis (Cahyadi et al., 2018), stable model builder, advanced editing (Fischer et al., 2019) and can analyze GIS data more deeply (Sare et al., 2013). This advantage makes ArcGIS usable up to an advanced level. The use of MCA in development planning is important to facilitate regional planning scenarios (Jato-Espino et al., 2014; Rikalovic et al., 2014; Aldiansyah & Wibowo, 2022; Arimjaya et al., 2022). The results of the MCA can be in the form of areas with alternative locations (Wibowo, 2009).

The study conducted by Keshkamat (2007) succeeded in presenting alternative areas of choice from an economic, environmental and social point of view to a combination of the three to connect Warsaw (Poland) and Postdam (Germany) using SMCE. Wibowo and Semedi (2011) also succeeded in presenting alternative areas with good access, hydrology, physiographic and comfort by taking into account the inhibiting factors for finding industrial locations in the middle of the urban matrix. The choices made can be applied to strategic analysis in the environment. Strategic Environmental Assessment (KLHS) is used to assess the policies made or planned that have carefully considered environmental aspects. KLHS was first im plemented in Indonesia in 2008-

2009, in collaboration with the Regional Development Planning Agency, the Ministry of Environment and the Ministry of Home Affairs as well as local governments, specifically the Regional Development Planning Agency and the Agency that manages the Environment. Several local governments have agreed to implement KLHS as a pilot project and have sent staff to study SEA in the Netherlands from 2009 to 2010. The legal basis for KLHS to date is clearly stated in the Law No. 32 of 2009, Government Regulation No. 46 of 2016 and the Regulation of the Minister of Environment and Forestry No. 69 of 2017. The purpose of this study is to determine and evaluate the appropriate industrial area based on the 2010-2030 Regional Spatial Plan for Kendari City using SMCE.

2. Methodology

2.1. Study Area

The application of SMCE was selected for a case study of Kendari City in Southeast Sulawesi (Figure 1). Kendari City has an absolute location of 03°54'40"LS - 04°5'05"LS and 122°26'33"E - 122°39'14"E with a total area based on the projection of the 51S UTM Zone covering an area of 27491.24 ha which is divided into 10 sub-districts. Kendari City has the potential for economic growth. Kendari City, as the provincial capital, intends to make regional plans to create a comfortable city. The objective and mission of the Settlement Development Strategy indicate that the new industrial sector will produce new employment. Therefore, the Kendari City government intends to place industrial area locations in areas that are considered strategic from all aspects.

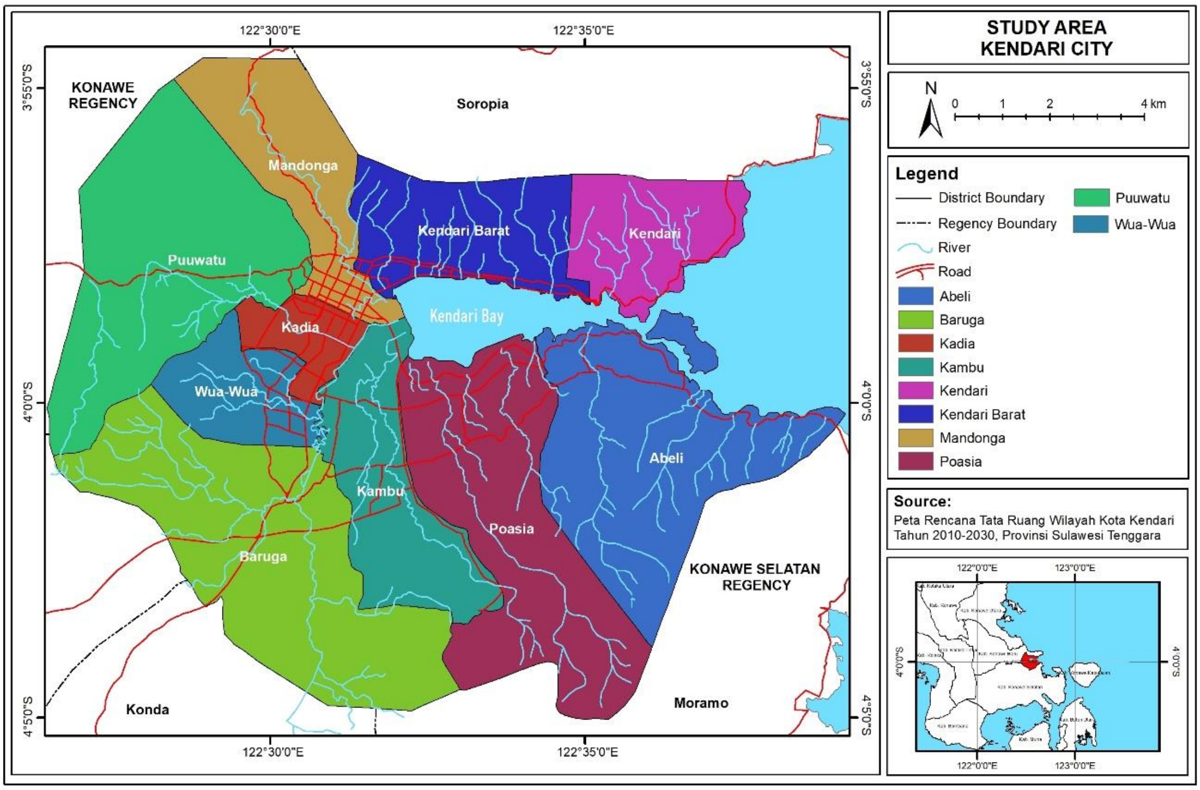

Figure 1. Area Study

2.2. Data Acquisition

The factors used in the available scenario models are based on a priority scale. Location characteristics and land suitability for industrial areas based on the Regulation of the Minister of Public Works and Human Settlements (KPUPR) Number: 41/PRT/M/2007 must consider the aspects of access, hydrology, physiography and comfort. The criteria for proximity to the road (access) use the "Cost" standard because the closer to the road, the better access to and from industrial locations (low cost). The criteria for proximity to the river (hydrology) use the "Benefit" standard because it is assumed that the farther the distance from the river, the better. This relates to government regulations which state that river basin areas may not be developed. Physiographic criteria using standardized "Group". This selection assumes that topography also has an important influence on the smooth process of industrial activities. The higher the industrial location, the greater the impediment to industrial activity. In addition to topography, the slope is also considered with the "Group" standard. This selection assumes that the slope greatly affects the stability of the land. Steep slopes tend to be less stable because landslides often occur and are prone to erosion which is indirectly dangerous to be designated as an industrial location. The flatter the slope, the better it is suitable for industrial locations. The criterion of distance from settlements (comfort) uses the "Benefit" standard because it is assumed that the farther the settlement is from the industrial location, the more comfortable the residential area will be in terms of noise and waste generation. These factors are presented in Table 1.

Table 1. Spatial Model Building Factors

Factor	Assumption	Standardization	Method	Data Type	Source
Access	The closer to the road, the more suitable (low cost).	Cost	Gaol	Vector	RBI Map 1:50.000 (2004)
Hydrology	The closer to the river, the less suitable (water pollution).	Benefit	Gaol	Vector	RBI Map 1:50.000 (2004)
Slope	The flatter the slope, the more suitable.	Group	-	Raster	30 meters SRTM image (2000) with standardization by BAPPEDA Kendari City
Topography	The lower the height, the more suitable.	Group	-	Raster	30 meters SRTM image (2000)
Comfort	The farther the location of the industry from the settlement, the more comfortable the settlement (noise).	Benefit	Gaol	Vector	RBI Map 1:50.000 (2004)
Inhibitor	Forests can't be changed because a city needs a forest.	-	Constraint	Vector	BAPPEDA Kendari City (2010)

Access data was taken from road data with other types of roads to arterial roads, hydrological data was taken from river data and comfort data was taken from settlement data; all three of which are sourced from Rupa Bumi Indonesia Map with a Scale of 1:50,000. Physiographic data in the form of slopes and elevations were obtained from the extraction of the 30 meters SRTM image, but the height data has been standardized by the Kendari City Regional Development Planning

Agency. The inhibiting data was obtained from data on land use and land cover in 2010. The use of data was prioritized on data sourced from the data agency because it is more reliable and is the data used in preparing regional spatial planning in Kendari City in 2010-2030.

The decision-making process in regional planning uses a scenario model with predetermined criteria and factors. Policymakers can choose from numerous different scenario model results available based on a priority scale. There are seven steps in conducting SMCE according to Wibowo and Semedi (2011). First, determine the focus (goals, aims, objectives). Second, depending on local government rules, define and categorize the criteria (factors/constraints). Third, the criteria must be scored. Fourth, standardize the criteria scores. The fifth consideration is the the weighting of the criteria. Sixth, consider the area suitability (stakeholder preferences/alternatives). Finally, decision making. The Weighted Overlay approach was used to select industrial regions in Kendari City based on data that indicated the criteria, which were free from inundation-prone areas, situated in a relative data area (20%), distant from settlements (600 meters), adequate accessibility, away from settlements and from the river to minimize water contamination caused by industrial waste (> 100 meters). There are constraint factors in SMCE that control whether or not anything should be developed. Forests in industrial area planning are an impediment since they cannot be created. This is to prevent forest areas from being turned into industrial sites.

2.3. Data Analysis

The study used a qualitative approach in interpreting and drawing conclusions based on predetermined criteria to select the appropriate industrial location based on the situation. The suitability model of the industrial area in Kendari City was evaluated visually using the Kendari City Regional Spatial Plan map for 2010-2030 to see the suitability of the location of the industrial area that has been planned at this time.

3. Result and Discussion

A scenario analysis involving varied factor weights with a total weight of 100% is performed in assessment to find the optimal industrial area. This process examines the suitability from several perspectives according to the importance of the criteria. The weight of each scenario is presented in Table 2. The scores used are presented in Table 3. The spatial description of the criteria used is presented in Figure 2.

3.1 Scenario A

Scenario A was carried out by giving the same weight, which was 20% to the five selected factors. The results of the scenario at SMCE for equal weight in Kendari City are presented in Figure 3. The color gradation shows that the redder the area, the less suited for industrial areas it is, and the greener the area, the more ideal for industrial areas it is. Figure 3 shows an area with green gradations that form blocks of circles that are wider than other areas (dotted black circles).

3.2 Scenario B

The B scenario process was carried out by assigning various weights with slightly different ranges, namely 10% and 35% of the five selected factors. The results of the scenario at SMCE for slightly different weights in Kendari City are presented in Figure 4. The color gradation shows that the redder the area, the less suited for industrial areas it is, and the greener the area, the more suitable for industrial areas it is. The findings of Scenario B reveal an intriguing fact: a weight difference of up to 10%-15% produces a discrepancy that is not significantly different from the weight comparison of the same value.

Table 2. Weight of Each Scenario

Spatial Data	Factor	Scenario Weight (%)										
		A	B					C				
		Equal	1	2	3	4	5	1	2	3	4	5
Distance from Road	Access	20	10	35	10	35	10	60	10	10	10	10
Distance from River	Hydrology	20	35	10	10	35	10	10	60	10	10	10
Slope	Slope	20	10	35	35	10	10	10	10	60	10	10
Altitude Region	Topography	20	35	10	10	10	35	10	10	10	60	10
Distance from Settlement	Comfort	20	10	10	35	10	35	10	10	10	10	60
LULC	Inhibitor	0	0	0	0	0	0	0	0	0	0	0

Table 3. The Score of Each Criterion

Spatial Data	Score					Constraint
	1	2	3	4	5	
Distance from Road	> 800	600-800	400-600	200-400	0- 200	-
Distance from River	0-100	100-200	200-300	300-400	> 400	0-100
Slope	> 25-40	15-25	8-15	0-8	-	-
Altitude Region	> 355-471	235-355	95-235	45-95	0-45	-
Distance from Settlement	0- 200	200-400	400-600	600-800	> 800	< 600
LULC	Pond, Water	-	Ricefield, Rainfed Rice Fields,	Settleme nt, Mixed Garden, Cashew, Coconut	Scrub, Reeds, Bush, Moor, Meadow,	Primary & Secondary Dryland Forest, Forest, Primary & Secondary Mangrove Forest

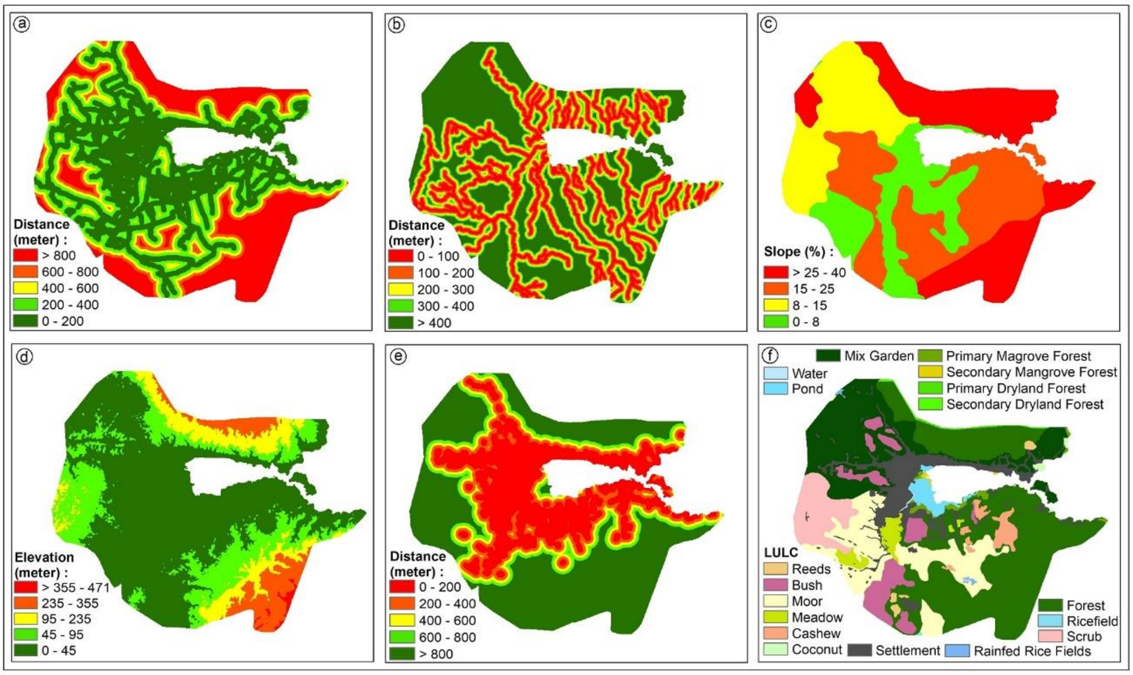

Figure 2. Criteria for Modeling using SMCE (a) distance from road; (b) distance from river; (c) slope; (d) altitude region; (e) distance from settlements; (f) land use and land cover.

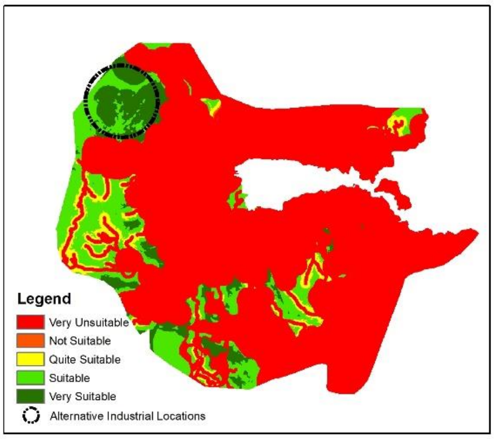

Figure 3. Scenario A yields the same weight

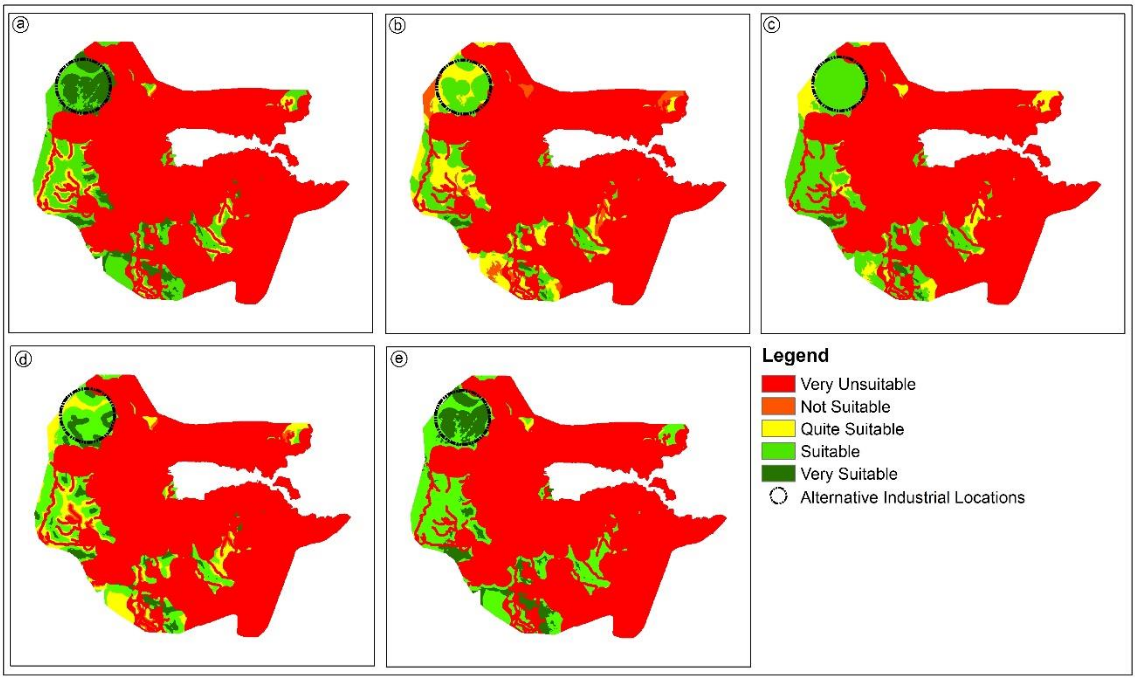

Figure 4. Scenario B yields slightly different weights: (a) weight 1; (b) weight 2; (c) weight 3; (d) weight 4; (e) weight 5.

Wibowo and Semedi (2011) similarly made this alteration with a change range of 5% and found it to be inconsequential. The result of the block area in scenario A is still visible in scenario B (dotted black circle). From all B scenarios, there is always one block area that appears in green (suitable to very suitable for industrial area) (Figure 4).

3.3 Scenario C

The C scenario process was carried out from a different (subjective) perspective by giving different weights with extremely diverse ranges to approximately 60% of the five selected factors. The result is presented in Figure 5. Scenario C in Figure 5.a emphasizes the access factor, which is 60%, to determine whether scenarios A and B exist in scenario C. The results show that block areas still appear but with a tendency of green and yellow with a little red color. This is an interesting finding if it is related to the road factor because a small part of the area which previously only consisted of green and dark green has been mixed with red. The development of industrial areas by emphasizing the road aspect can result in the flow of products transportation being mixed with the traffic flow of the city residents. This causes congestion and traffic problems that can disrupt the activities of the city residents as well as the transfer of commodities via road access, and this intersection also has a significant influence on reducing road performance, especially during peak hours (Petyasari, 2018).

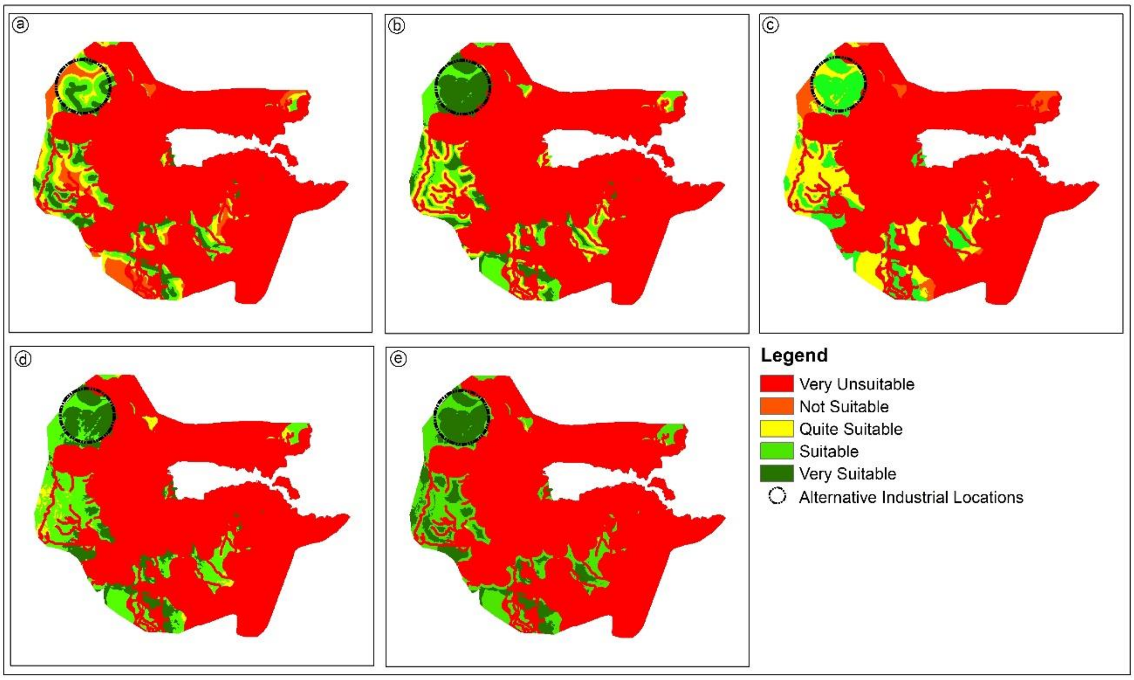

Figure 5. Scenario C yields different weights (a) weight 1; (b) weight 2; (c) weight 3; (d) weight 4; (e) weight 5.

Scenario C in Figure 5.b emphasizes the hydrological factor, which is 60%. The results show that the color of the block area is dominated by green and dark green (suitable and very suitable). This aspect is quite important considering that the main cause of the existence of industrial areas in the area around the river will only cause river pollution (Gbarakoro et al., 2020). Scenario C in Figure 5.c shows that with a 60% weight emphasis on the physiographic factor of the slope, the results of the block area are light green and yellow. Scenario C in Figure 5.d with an emphasis on the physiographical aspect of the altitude area of 60% shows the same results as scenario C in Figure 5.b but with a green color dominance (suitable). Geomorphological factors influence the conversion of vegetated area into a developed area (Aldiansyah et al., 2021), but this will reduce slope stability caused by slope excavation due to shifting soil mass (Sutejo & Gofar, 2015).

Scenario C in Figure 5.e with emphasis on the comfort aspect with a weight of 60% shows that there are similarities with scenarios C 5.b and 5.d in Figure 5, which are dominated by green and dark green colors (suitable and very suitable). Industrial areas should be developed far from settlements to avoid harming residential conditions due to a lack of income, road damage, decreased water availability from Regional Drinking Water Company (PDAM) and the possibility of failing to paying attention to facilities and infrastructure around residential areas (Kristiani et al., 2015). The availability of green open space in Kendari City is still insufficient to meet green open space standards (Aldiansyah, 2021). The development of industrial areas around residential areas will only continue to reduce the green open space area (Kristiani et al., 2015). This will become more serious if it continues considering the rate of change in land use and cover in Kendari

City, which is an integral part of the watershed area and is projected to become a built-up area (Aldiansyah et al., 2021; Rahmi et al., 2022; Aldiansyah & Saputra, 2023).

3.4 Final Alternative Result of Industrial Area

Scenario A shows the areas identified as being suitable for Industrial zones. The results of scenario A were then tested with a spatial model in Scenario B, and the results show that the area seen in Scenario A is still visible in Scenario B. In Scenario C, the spatial model emphasizes one component that is more important than others. The results show that the block still appears despite changes in the weights of each criterion. Based on Scenario 2.c, more emphasis was put on the hydrological factor, which was 60%. This scenario is preferable because the river area from Kendari City to the bay has been heavily polluted and declared to have exceeded the threshold due to high community activities (Sahabuddin et al., 2014; Wibowo et al., 2020). The results are visible for the area of suitability ranging from very unsuitable to very suitable (Table 4) and are illustrated in Figure 6.

Table 4. Area of Suitability

Suitability	Area (ha)	Percentage (%)
Very Unsuitable	21.314,70	77,53
Not Suitable	56,59	0,21
Quite Suitable	1.467,47	5,34
Suitable	2.190,12	7,97
Very Suitable	2.462,36	8,96

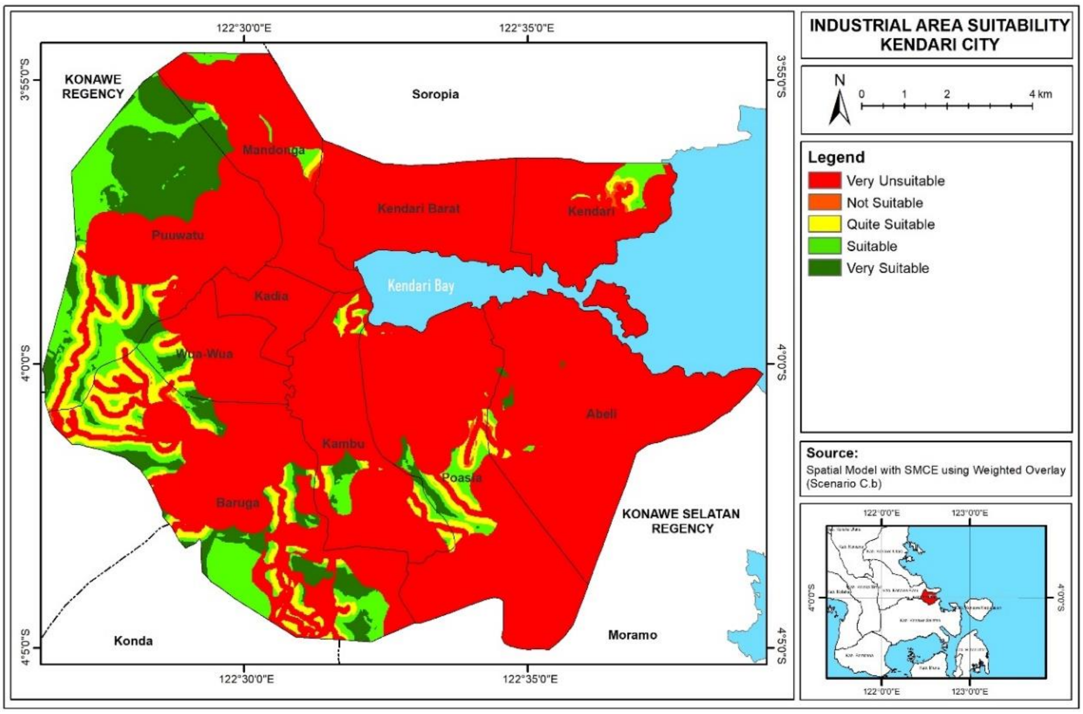

Figure 6. Map of Suitability of Industrial Area in Kendari City

According to the analysis of the results of Scenarios A, B and C, the location that is very suitable for the Industrial area in Kendari City based on factors of Access, Hydrology, Physiography and Comfort, covering an area of 2,463.36 ha is Puuwatu Sub-District.

3.5 Regional Development Evaluation

A comparison of the industrial area suitability model with the Kendari City spatial plan in 2010-2030 shows a mismatch (the dotted blue circle is the determined industrial location and the dotted black circle is the alternative industrial location from SMCE analysis) in Figure 7. Figure 8 depicts the area that is planned to become an industrial area on the regional spatial plan map in two locations: Abeli and Puuwatu Sub-Districts (middle part). Following an evaluation based on the selected criteria, the two locations were determined to be unsuitable for development as industrial areas. The industrial area plan in Abeli Sub-District shows a gradation of red, indicating that the area is not very suitable to be used as an industrial area. Puuwatu Sub-District (the middle part) shows various color gradations, with just a limited area suited for industrial operations.

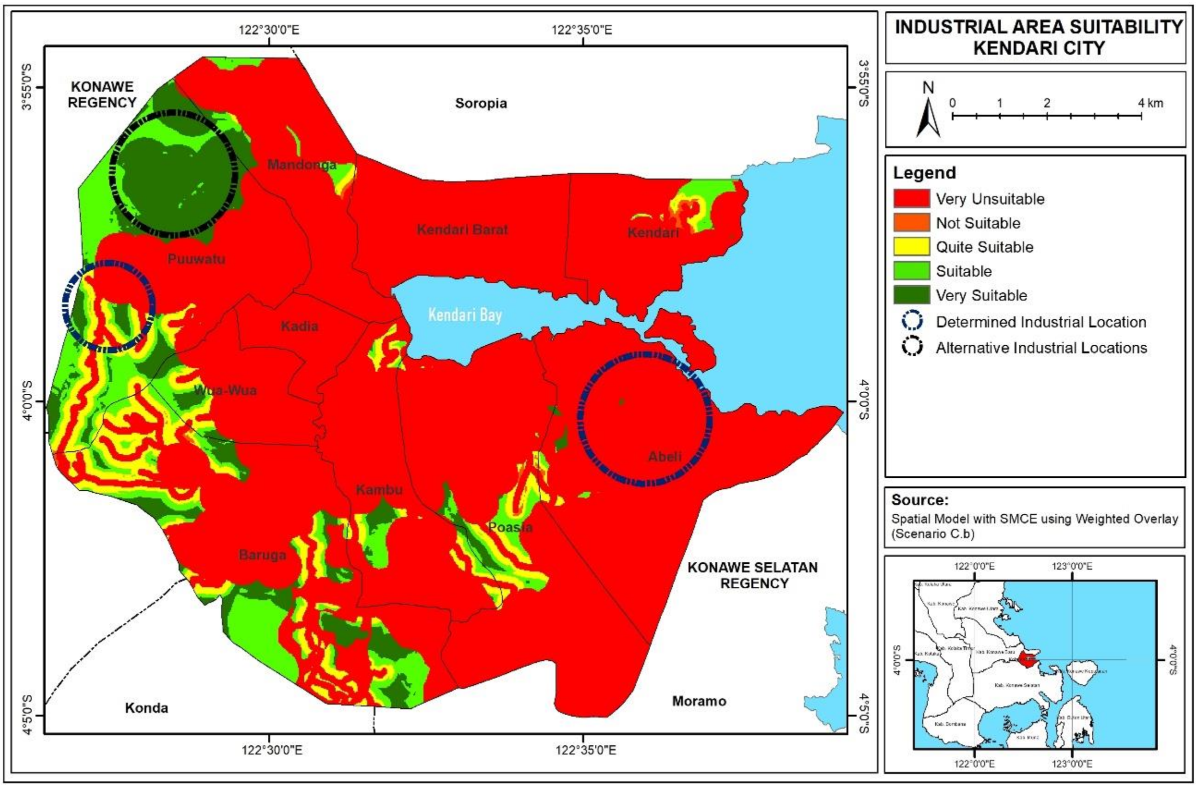

Figure 7. The suitability of the industrial area

Based on the model results , there is only one possible alternative that can be taken by decision-makers in Kendari City, which is Puuwatu Sub-District which is directly adjacent to Mandonga Sub-District, because this area is not a forest area so there are no constraints on land cover. The local government of Kendari City needs to conduct a review regarding the selection of Industrial Area locations based on the Kendari City Regional Spatial Plan for 2010-2030.

4. Conclusion

The industrial area in Kendari City is located in the Puuwatu Sub-District which borders the Mandonga Sub-District with an area of 2462.36 ha which was generated by spatial modeling with SMCE. The best scenario is scenario 2.C where the aspect of proximity to the river is taken into account. Kendari City has a fairly high-density of the river network, while in this scenario it is far enough from the river so that it can minimize the river areas that have been heavily polluted physically,chemically and microbiologically. Meanwhile, the worst scenario is shown in scenario 2.B where aspects of access and slope are taken into account. Even though the industrial location greatly benefits from this scenario, this scenario will greatly harm the ecological and environmental aspects.

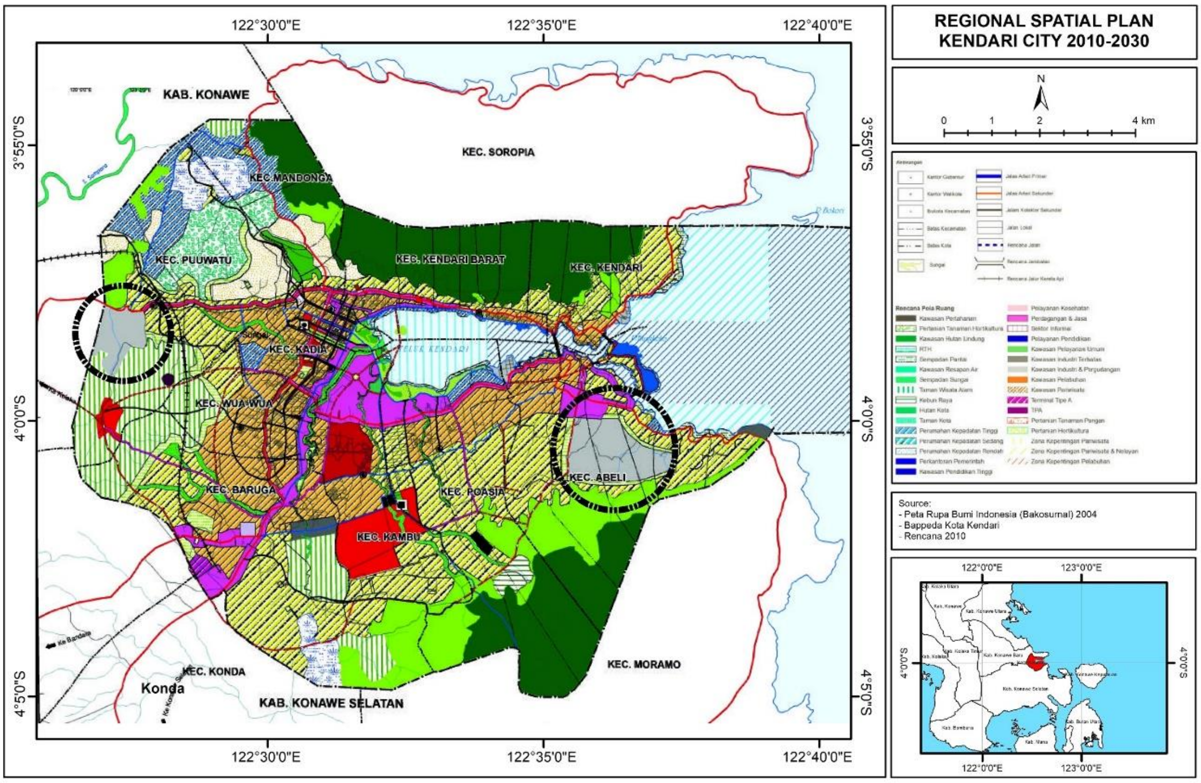

Figure 8. Evaluation of the Kendari City Regional Spatial Plan in 2010-2030

The Kendari City spatial plan for 2010-2030 shows a discrepancy with the scenario model. The scenario model shows that Puuwatu District which is directly adjacent to Mandongan District is very suitable for industrial areas. This research also shows that development policies, plans and programs, especially for industrial estates, are not in line with the sustainable development aspects as stated in the SEA. It is necessary to rearrange the Regional Spatial Plan for Kendari City to avoid problems in the future.

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