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Suitability Mapping for Broiler Closed House Farm Using Analytical Hierarchy Process and Weighted Overlay with Emphasize on Environmental Aspects

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Abstract: Massive development of broiler farms has led to many socio-environmental problems. A mapping based on the socio-environmental factors and sustainable principles is urgently needed to cope with this problem. The objective of this research was to create a suitability map for broiler farm development in Parung region, Indonesia-as study area. There were four factors considered in the mapping: (1) ecology and environmental impact, (2) economic and infrastructure, (3) natural condition and (4) natural disaster vulnerability, each of which consists of sub-factors. An Analytical Hierarchy Process (AHP) by using pairwise comparison method was applied to determine weight of each factor and sub-factor based on experts' valuation. From the AHP process, natural condition was considered as the most important factor, followed by ecological and environmental impact factor. By considering weights resulted from the AHP, the spatial analysis and weighted overlay by GIS software were applied in the data processing and suitability map building. Suitability map for broiler farm in Parung region has been created and can be used as guidance for broiler farm development and also for local government as decision support tool to manage the farming area concerning ecology and environment factor.

Key words: Analytical hierarchy process, broiler, environmental factors, mapping, site selection

INTRODUCTION

High population growth rate leads to the increasing demand for high-quality and high quantity animal protein as well. Directorate General of Livestock and Animal Health, Republic of Indonesia (2013) reported that the consumption of broiler meat is increasing from year to year. In 2006, the national consumption rate was 3.076 kg/capita/year and in 2012 was 3.494 kg/capita/year. By an increasing demand, it is necessary to meet the needs by increasing the production of animal protein. One animal protein producers is broiler meat. Broiler meat has comparable nutritional value to beef but the price is relatively lower than meat from cattle.

Many broiler farms are built to increase production and as positive respond to the increasing demand. However, the massive development of broiler farms has led to many socio-environmental problems, such as bad odor from manure (Rachmawati, 1999). A farming technology called closed house has been developed to overcome this negative impact. However, the same case with the other business development, closed house farm development should also consider three important aspects of sustainable development: economic, social and environment. A mapping based on the socio-environmental factors and sustainable principles is urgently needed to cope with this problem.

Currently, the development of information system and technology are really fast. Involving the development of geographic information system (GIS) as a computer-based information system that enables capturing, modeling, storing, retrieval, sharing, manipulating, analyzing and presenting geographic referenced data. GIS can also be used to determine suitable location of broiler farm which will be environment friendly. One capability of GIS can be utilized to determine suitable location for farm development is through multi criteria analysis (MCA). The MCA conducts many criteria that can produce several alternatives. In order to carry out the idea, it is necessary to generate compromise alternatives and a ranking of alternatives according to their degree of attractiveness (Jansen and Rietveld, 1990; In Hossain and Das, 2010). The integration of MCA within a GIS context could help users to improve decision-making processes. MCA has been used with GIS to analyze spatial problems for about two decades (Greene *et al*., 2011). One of the most popular method of MCA is analytical hierarchical process (AHP) which is a systematic method to guide decision-makers in making decisions to solve the problems based on priorities. AHP is one method in MCA found by Saaty (1980) who describes AHP as a theory of measurement through pairwise comparisons and relies on the judgements of

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experts to derive priority scales (Saaty, Decision making with the analytic hierarchy process, 2008).

Many researches have been done concerning the use of GIS in determining suitable location for animal farm. However, in Indonesia, especially in Parung Region, there is no report of research that has been done according to the utilization of GIS for poultry farm. Liaghat *et al*. (2013) has done a research about multi criteria evaluation using AHP technique to analyze coastal tourism sites in Port Dickson district in Malaysia. Another research applying AHP done by Nekhay *et al*. (2008). Prawiradiputra (2008) did a research about land suitability for dairy cattle farm selection using spatial analysis and AHP in Nanggroe Aceh Darussalam, Indonesia. In poultry field, formerly, Fitriadi (2011) did a research in Singkawang, Indonesia-by conducting two different regulations as considered criteria: Indonesian regulation and Australian regulation.

The objective of this research was to create a suitability map for broiler farm development for the current condition in Parung, Bogor, Indonesia. Parung is one region in Bogor Regency, West Java Province, Indonesia. Based 2014 data, the population of broiler farm in Parung was 1,045,903 heads of broiler makes Parung as the fourth highest population of broiler farm in Bogor Regency. Yet, Parung is one of the most developed region in Bogor. Thus, possibility for socio-environmental conflict might be high. The result of this research was expected to be used as a guidance for regional planning, so that the government can manage the zone for broiler farming which will not affect to socio-environmental conflict.

MATERIALS AND METHODS

This research was conducted in Parung, Bogor Regency, West Java, Indonesia as study area. Digital map was used in multi-criteria analysis method. Table 1 shows the detail of whole data used. GIS software and AHP software were used as supporting tools.

Collecting expert's preferences to rank factors: Questionnaire was used to obtain expert knowledge and preference according to importance of each determining factor. The respondent for the questionnaire were vary from governmental institution, private company and academician. The questionnaire was in the form of pairwise comparison for each factor and sub-factor and arranged based on hierarchy as shown by Fig. 1. Pairwise comparison is a method that used to calculate the expert assessment of each criteria used in this study. Pairwise comparison method was developed by Saaty (2008) as part of AHP.

Expert's judgement of the relative preferences or importance of one factor to another is expressed in numerical values. Saaty (1988) suggested a scale for pairwise comparison, consisting of value ranging from 1 to 9 describing intensity of importance. The value of 1 expresses one factor has the same importance to another factor. While the value of 9 is given to those factors whose importance is extremely importance to another factor. Table 2 shows the scale value for pairwise comparison in AHP.

Table 1: Data required for evaluation

Data	Format	Source
Road network	Vector	Bappeda
River network	Vector	Bappeda
Administrative	Vector	Bappeda
Land use	vector	BIG
Electricity supply	Vector	PLN
Digital elevation model (DEM)	Raster	USGS
Disaster vulnerability	Tabular	BPBD
Climatic data	Tabular	BMKG

Bappeda: Agency of Regional Development and Planning
BIG: Agency of Geospatial Information
PLN: National Electricity Company
USGS: United States Geological Survey
BPBD: Agency of Regional Disaster Management
BMKG: Agency of Meteorology, Climatology and Geophysics

Table 2: Pair wise comparison scale for AHP preferences (Saaty, 1988)

Preferences expressed in numerical value	Preferences expressed in linguistic value
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate value between adjacent scale values

The expert's judgement from questionnaire then synthesized by using AHP software to obtain the weight for each factor and sub-factor. Consistency ratio (CR) was used to analyze the quality of questionnaire filling. Judgment consistency can be checked by taking the CR of Consistency Index (CI) with the appropriate value (Ziaei and Hajizade, 2011). Value of CR was also obtained from AHP software. Reassessment would be done if the value of CR exceed 0.1 (CR>0.1).

Building suitability map: This research considered four main factors: (1) ecological and environmental impact (ECO), (2) economic and infrastructure (ECI), (3) natural condition (NAT) and (4) natural disaster vulnerability (DIS). Table 3 shows the factors and constraints that used in multi-criteria analysis in this research.

Distance from settlement was considered due to the odor from broiler farm and to minimize noise from settlement that can disturb the broiler chickens, which can influence their productivity. Also to minimize negative impact of ammonia and carbon dioxide from the farm which can negatively affect people around the farm, as stated by Killic and Yaslioglu (2014). Distance from river or water body was related to waste disposal. Waste from

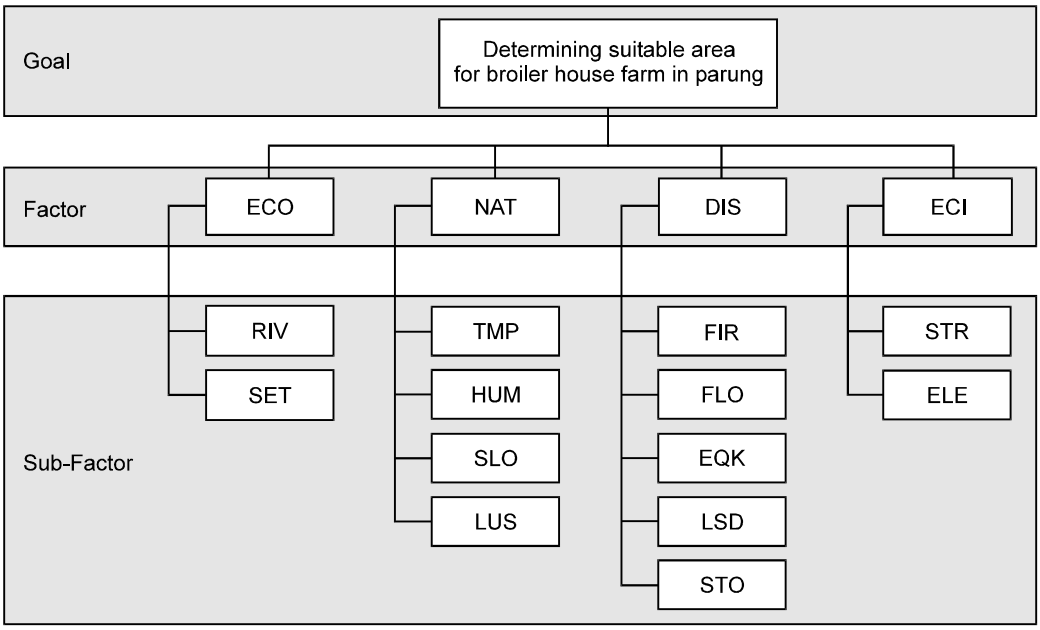


Fig. 1: Hierarchy of goal, factor and sub-factor

poultry house was considered not good to environment. Although the waste management in some broiler farm was already good, building broiler farm as far as possible from river will be better to decrease waste negative impact. Factors included as economic and infrastructure factor were: distance from/to road and electricity supply. Distance from/to road related to easiness of one location to be discovered. Closer location impacted to the cost by the farmer to transport farm material to come in to the farm and harvested broiler chicken to go out of the farm. Broiler farm needs electricity supply to use for several electricity equipment, such as: lighting and water pump. Thus, the availability of electricity is obligatory. Local climate as natural factor was counted to its stimulation effect on the characteristic to broiler chicken to environment change. One local climate factor considered in this study was temperature, as stated by Park *et al.* (2015) that the higher environmental temperature reduced the ADFI, feed cost and total cost but increased total income in the commercial broiler farms in Korea. However, this effect can influence the growth thus body weight as the main objective of broiler chicken farming. Land elevation and slope, soil type and land use were factors to determine the possibility of broiler farm development location. This research considered also natural hazard as influencing factor. Area with high vulnerability of natural hazard has to be avoid.

The whole factors mentioned above were ranked by using AHP and processed through sequence step in spatial analysis to build suitability map. Weight from AHP process was used in weighted overlay in GIS software. Overlay is spatial analysis by combining at least two layers of data as input. The overlaying was done by performing arithmetic process on each pixel of input data to produce new pixel as output data. Weighted overlay was an overlay process that uses weights for each factor. In the weighted overlay process, the input data is in the form of raster data, which located and stored data using a matrix structure or pixels that make up the grid. Weighted overlay method was used in this research because of its simple and straightforward technique especially for spatial inference using multi-classes maps (ESRI, 2002). Basically, spatial analysis can also be simply done by using Boolean logic. In Boolean logic, the suitable area on the final suitability map are the area which fulfill the whole criteria. The involved variables are considered to have the same importance. Thus, as stated by Carvalho *et al.* (2007), weighted overlay operations allow a more flexible map combination compared to Boolean logic operations.

The weighted overlay was done hierarchically based on AHP hierarchy of factors and sub-factors. Generally, determination of suitable area for broiler farm in this research was modeled as follow:

$$SA_x = \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \ldots + \alpha_n X_n$$

where, SA_x: Suitability of area based on factor X.
α_i: Weight of factor X_i. Ranged from 0 to 1 ($\Sigma\alpha_i = 1$).
X_i: Score for factor X_i.

Suitability of an area was determined based on the final score on the weighted overlay outputs. Figure 2 show an example of weighted overlay process of two maps of factor A and factor B.

Table 3: Factor and constraints considered to build suitability map

	Class				
Factor sub-factor	Very unsuitable (score: 1)	Unsuitable (score: 2)	Moderate (score: 3)	Suitable (score 4)	Very suitable (score: 5)
ECO					
Distance from settlement (m)	<50	50-100	100-150	150-200	>200
Distance from river (m)	<50	50-100	100-125	125-150	>150
ECI					
Distance from road (m)	>250	200-250	125-200	75-125	<75
Distance from electricity network (m)	>200	150-200	100-150	50-100	<50
DIS					
Storm vulnerability	high		medium		low
Flooding vulnerability	high		medium		low
Land slide vulnerability	high		medium		low
Earthquake vulnerability	high		medium		low
Fire vulnerability	high		medium		Low
NAT					
Land slope	>25°	9-25°	6-9°	1-6°	<1°
Land use type	Settlement/build area, water body	Rice field	Plantation	Tegalan, ladang	Bush, bare land
Maximum temperature (°C)	>30°C		25-30°C		<25°C
Maximum humidity	>80%		70-80%		<70%

ECO: Ecology and environmental factor, ECI: Economic and infrastructure, DIS: Natural disaster vulnerability, NAT: Natural condition

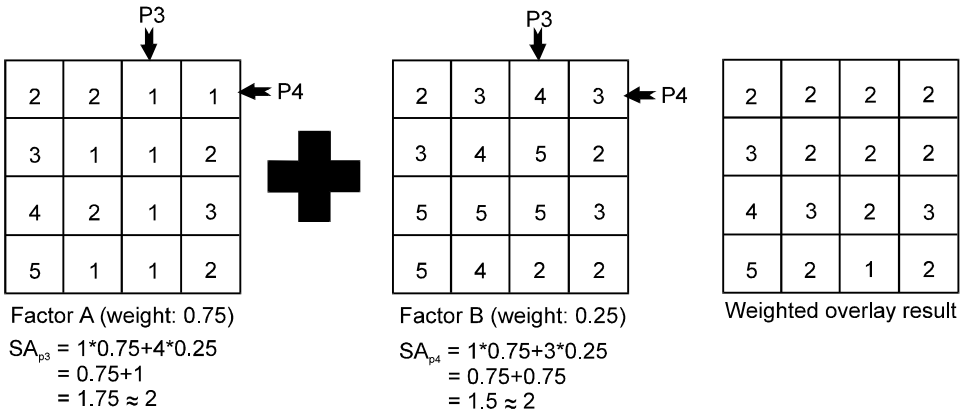


Fig. 2: Example of weighted overlay process

Once the final score is obtained, the area on the map will be classified into five classes based on the final score. The level of final score for determining suitability was as follows:

1: 1.00-1.99 = Mostly unsuitable
2: 2.00-2.99 = Unsuitable
3: 3.00-3.99 = Moderate suitable
4: 4.00-4.99 = Suitable
5: 5.00 = Mostly suitable

RESULTS AND DISCUSSION

Expert preference for determining each factor weight: All questionnaires from each respondent has been processed by AHP method using AHP software. From the processing results, it was known that the quality of the questionnaire filling by some respondents was not good enough. It was found from the value of consistency ratio (CR) which was more than 0.1 (>0.1). However, a reassessment was done to improve the consistency ratio values of each respondent. So that all questionnaires from each respondent had consistency ratio value less than 0.1 (<0.1). The results of AHP processing of weight for each factor is shown in Table 4. From the table, according to weight, natural conditions was the most important aspect, followed by ecology and environmental aspect. While the natural disaster vulnerability was the least important aspect. This result implied that respondent also had a concern to the ecology and environmental aspects. The same result also can be found in natural conditions aspect which had the highest weight. In natural conditions aspect, land use type had the highest weight means the most important aspect in natural condition. In land use type aspect, many ecology and environmental factors were considered. This aspect also respect to the regulation which regulate the development of new farm should be not located on prohibited land use type and even, not

located on surrounding of prohibited land use type. Mostly of the regulation said that poultry farming is essentially a rural activity and new poultry farms should be located on rural zoned land (Western Australia Planning Commission, 2003). Distance from settlement in ecology and environmental aspect in this study could cope with this regulation. Every new poultry farms should be established in locations suitable to their operational requirements, to minimize the impact of poultry farms on residential, rural-residential and other potentially incompatible uses. In ecology and environmental aspect, distance from settlement considered as the most important factor.

Spatial analysis: Suitability map was developed by using weight from AHP process in the previous step. Figure 3 shows the weighted overlay process for the main factors. Final suitability map resulted from combining the four map based on each weight.

From the figure, it can be seen that suitable location was mostly located in Iwul, at the southern area of Parung. Figure 4 shows more detail information about percentage of each suitability class for each desa/region. The largest suitable area found in Iwul, by total area of 109.56 ha. While the smallest suitable area found in Bojongindah (0.01 ha) and Parung (0.11 ha). This result match to the fact that Parung has the highest

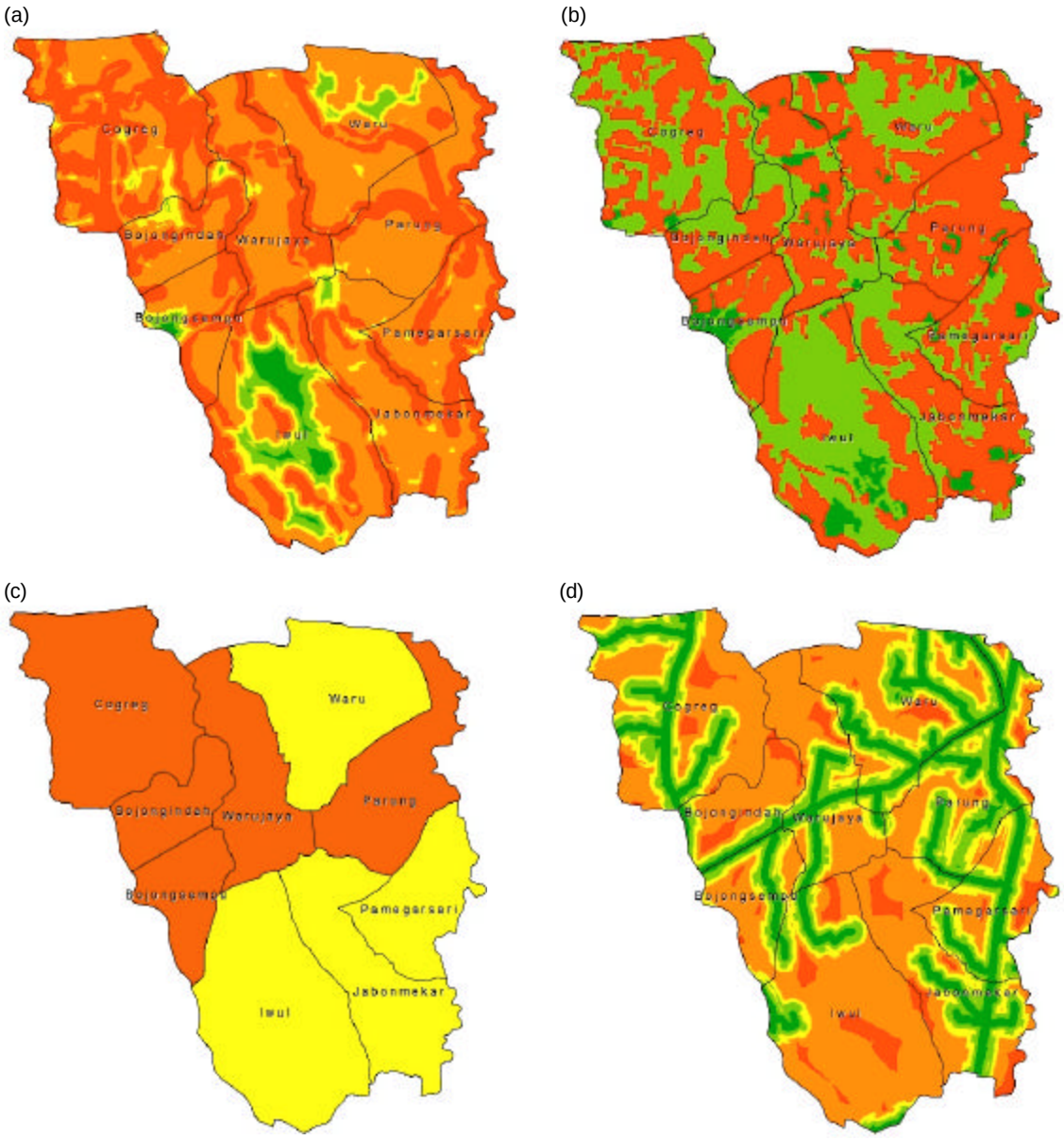


Fig. 3: Continue

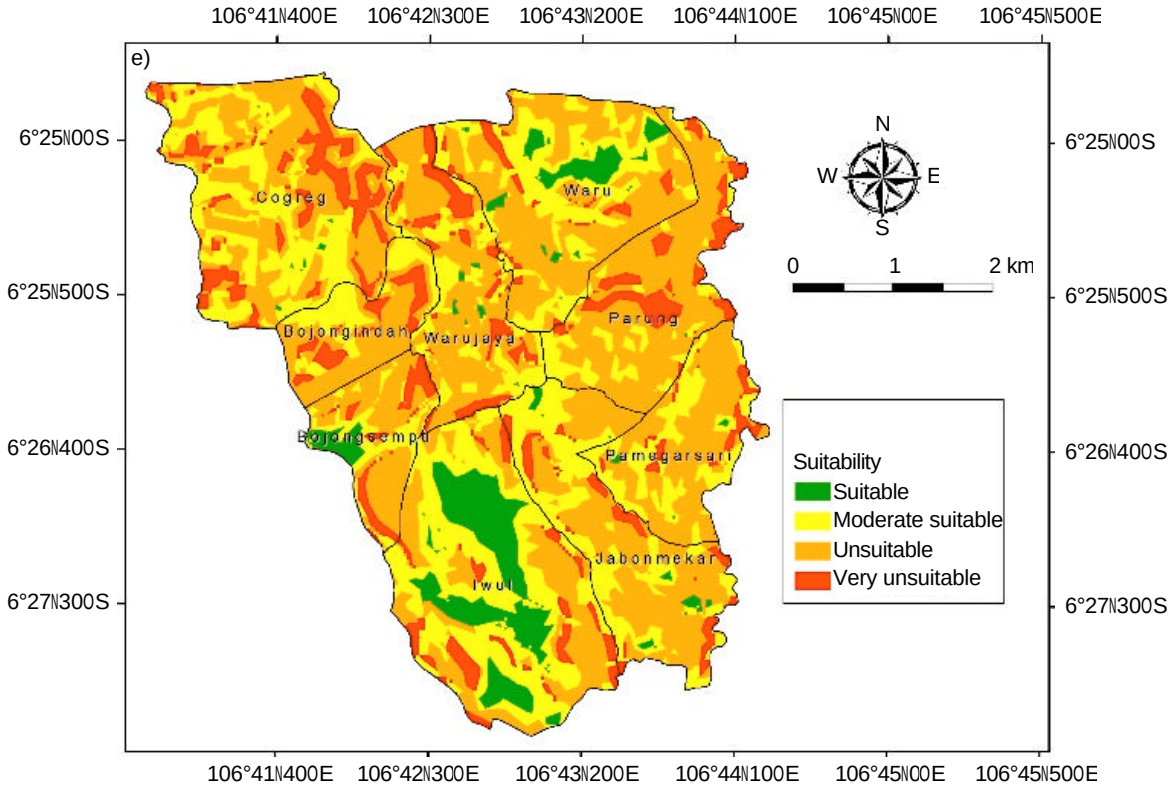
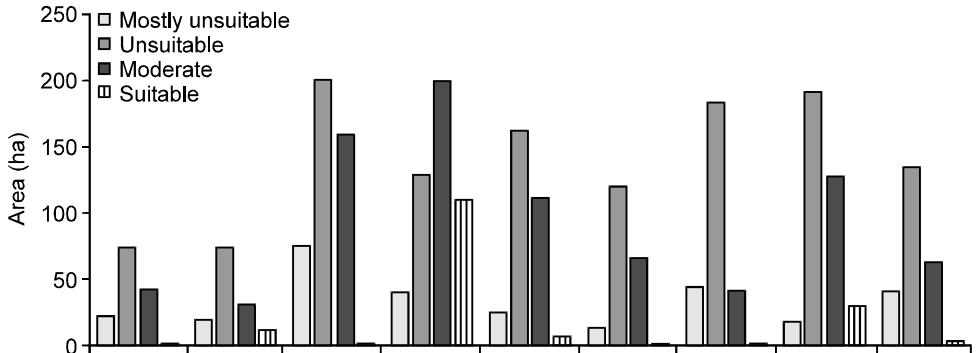


Fig. 3: Spatial analysis for four main factors: ecology and environmental impact (a), natural conditions (b), natural disaster vulnerability (c), and economic and infrastructure (d). Four factors were overlaid based on each weight become suitability map based on all factors (e)



	Bojongindah	Bojongempu	Cogreg	Iwul	Jabonmekar	Pamegarsari	Parung	Waru	Warujaya
Mostly unsuitable	22.09	20.26	75.43	41.1	25.03	13.89	44.8	17.41	40.9
Unsuitable	74.18	74.13	199.86	128.19	162.03	119.37	182.57	191.33	134.03
Moderate	42.45	30.77	160.46	199.97	110.74	65.86	41.36	127.35	62.2
Suitable	0.01	12.32	1.35	109.56	6.23	1.22	0.11	29.82	2.88

Fig. 4: Area of each suitability class for each desa/region

population density and the most developed area in Parung region. High population density theoretically decreases the suitability for broiler farm, especially by concerning ecology and environment aspects. The southern area, which was less developed area, has the largest suitable area. Thus, for sustainable development

Table 4: AHP result in weight for each factor and sub-factor

Factor	Weight	Sub-factor	Weight
ECO	0.34	Distance from settlement	0.75
		Distance from river	0.25
ECI	0.14	Distance from road	0.27
		Distance from electricity network	0.73
DIS	0.12	Storm vulnerability	0.12
		Flood vulnerability	0.35
		Land slide vulnerability	0.21
		Earthquake vulnerability	0.19
		Fire vulnerability	0.13
NAT	0.40	Land slope	0.10
		Land use type	0.33
		Average temperature	0.25
		Average humidity	0.32

purpose, broiler closed house farm development in Parung region should be located in the southern area.

Implications: This research result which was in the form of suitability map can be used directly as a guidance for the farmer to choose the best location to build broiler farm. It is recommended that the government can use this suitability map as decision support tool to manage zoning for broiler farming concerning ecology and environment. Also, since there is no specific regulation according to poultry farm establishment concerning ecology and environmental impact, it is recommended that the local or central government in Indonesia to arrange the regulation. For processing companies and farmers, it is recommended that processing companies and farmers become more involved in farm environmental issues and the impact of farm closure on processing line efficiencies.

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