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Research Article

Assessing the Suitability and Availability of Land for Agriculture in Tuban Regency, East Java, Indonesia

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Indonesian food production depends highly on Java Island, which holds the most fertile soils in the country but had limited area. The objective of the research was to analyse the availability of suitable land for agriculture in Tuban Regency, an agricultural regency in Java Island. Land suitability was evaluated with spatial multicriteria analysis, integrating soil order, land capability, elevation, slope, slope direction, land use/land cover, accessibility, and climate. Land availability was analysed, integrating the forest area status designation and the spatial pattern of regional official land use plan. The results indicated that suitable land for agriculture corresponds to 91% of the total study area, confirming the high soil fertility. Analysis of land availability then indicated that 18% of the area was both suitable and available for agriculture. Considering the actual land utilization, the future development of agriculture in the region has less than 7% of the land area left for agricultural expansion. The overall results showed the importance of looking for land allocated for agriculture outside Java Island to anticipate the need for food of a country with a high population growth rate and also developing planning for food production.

1. Introduction

The world is increasingly felt smaller because of rapid population growth that has resulted in an increasing need for land. The fact that land has to be used by many sectors and that there is the necessity to meet growing food demand in a sustainable way means that land use planning is necessary [1]. The core of land use planning is the land suitability for a given utilization; therefore, it is necessary to evaluate land suitability [2]. Land evaluation is the assessment process of land performance for specific purposes [2, 3]. Assessment results can then be used to predict the land's potency for certain utilizations [3]. The selection of land is important, because using unsuitable land will have implication for low production, which in turn results in the inefficient utilization of resources [4].

Land evaluation is done through assessment of land quality and land characteristics indicators in terms of physical aspects as well as economic, social, and environmental aspects [2, 5]. Facilitated by recent advances in technology, land evaluation was developed in integrated ways, based on multicriteria decision-making concept [6, 7]. The combination of analytical hierarchy process (AHP) with geographic information system (GIS) in a method which is known as multicriteria analysis (MCA) is one of the methods of decision-making in land use planning [8]. MCA has been used for various purposes, including agriculture [9].

Practically, land suitability alone would not be sufficient for planning land utilization. Land which is suitable for a given use may actually have been used for or have been allocated for another use. Therefore, when planning land utilization, it becomes important to conduct land availability analysis as well. The problem for the agricultural sector is that often the land utilization for agriculture is surpassed by the use of a variety of other sectors because agriculture has

a lower land rent, for example, compared with industrial and residential land utilization [10].

Such a situation has occurred on Java Island, Indonesia, which is the most fertile island in the country. The island has been the main food provider of the country; however, due to increasingly rapid population growth, nonagricultural land utilization has increasingly put pressure on agricultural land, in turn putting pressure on national food security [14]. The data from the last census indicated that the population of Indonesia was 237 million in 2010 [15] and has been estimated to become 255 million in 2015 [16], an increase of 7.6% during last 5 years. This number makes Indonesia become the fourth largest country in the world by population. Rice is the staple food for 95% of the Indonesian population [17]; however, most rice was produced from paddy fields in Java Island. Of the total 13.8 million ha of paddy fields in Indonesia, 6.5 million ha or 46.7% was in Java Island [18]. The paddy fields in Java Island produced 52.6% of Indonesia's total rice production, suggesting the very high Indonesia's dependence on Javanese agriculture. The problem is that Java Island is an island with a limited area that is inhabited by the majority of the Indonesian population. More than 136 million people or 57.5% of the population [17] lived on this island. With the island's area making up less than 7% of the total area of Indonesia [17], the very high dependence on Javanese agriculture is very risky for future national food security. In this most populous island, there is high pressure on agricultural land due to the need for infrastructure such as housing, roads, and industry.

Tuban Regency is one of the agrarian regencies in Java Island, with a population density of 701 person km^{-2} [19], which signifies that the regency is less populated for a Javanese regency. In comparison, the average population density of Java Island was 3,408 person km^{-2} in 2014 [17], while the density of Jakarta, Indonesian capital, was 15,015 person km^{-2} [17]. The methodology for this study was developed to investigate whether lands with high suitability level are available for agriculture and if this agrarian regency still can be developed for agriculture.

The objectives of this study were (i) to delineate the land at various levels of suitability for agriculture and (ii) to examine how many of such suitable lands are available for agriculture. The output of the study may provide the information for developing policy that needs to be set in relation to Indonesia's high dependence on Javanese agricultural production.

2. Materials and Methods

2.1. Research Area. The study was conducted in Tuban Regency, East Java Province, which is geographically located at 111°34′11″ to 112°13′23″ east and 6°45′10″ to 7°9′57″ south (Figure 1). The study area has a wet tropical climate with an average annual rainfall of 2,132.7 mm [19]. The monthly average temperature ranges from 26.6°C to 28.9°C. The elevation of the study area ranges between 0 m and 500 m above sea level (a.s.l.). The north and south parts of the study area are lowlands with a height of 0–50 m a.s.l. and are located around the coast in the north part and along the Solo River in the south part. The area with an altitude above 100 m a.s.l.

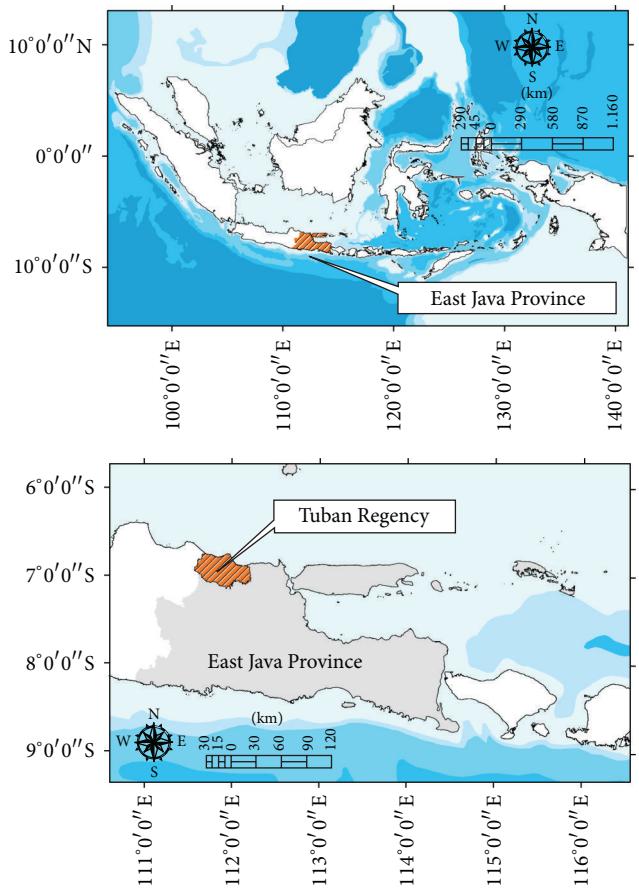

Figure 1: Study area of Tuban Regency, East Java.

is located at the centre of the region, extending from west to east [11, 20].

Observation from 1 : 100,000 geological maps [21] showed that the study area was developed from sedimentary rock; the geological formations are generally carbonate rocks. Volcanic rock formations also appear and are formed by quaternary to tertiary Oligocene rocks. The northern part of the region, the coastal area, was developed from alluvium material.

2.2. General Analysis Procedure. Two groups of evaluation methods were used, namely, land suitability evaluation and land availability evaluation (Figure 2). Land suitability evaluation was conducted using the MCA procedure. Four parameters were used, consisting of eight criteria; each criterion consisted of several subcriteria. The land availability was analysed using the spatial overlay of two parameters: forest area status designation (FASD) and land allocation in spatial patterns of regional official land use plan (SP-ROLUP). The results of land suitability and land availability evaluations were then analysed to obtain suitable land which is available for agriculture.

2.3. Land Suitability Evaluation

2.3.1. Criteria Used and Data Sources

Land Parameter. The land parameters used in this research consist of soil class and land capability class as criteria. Soil

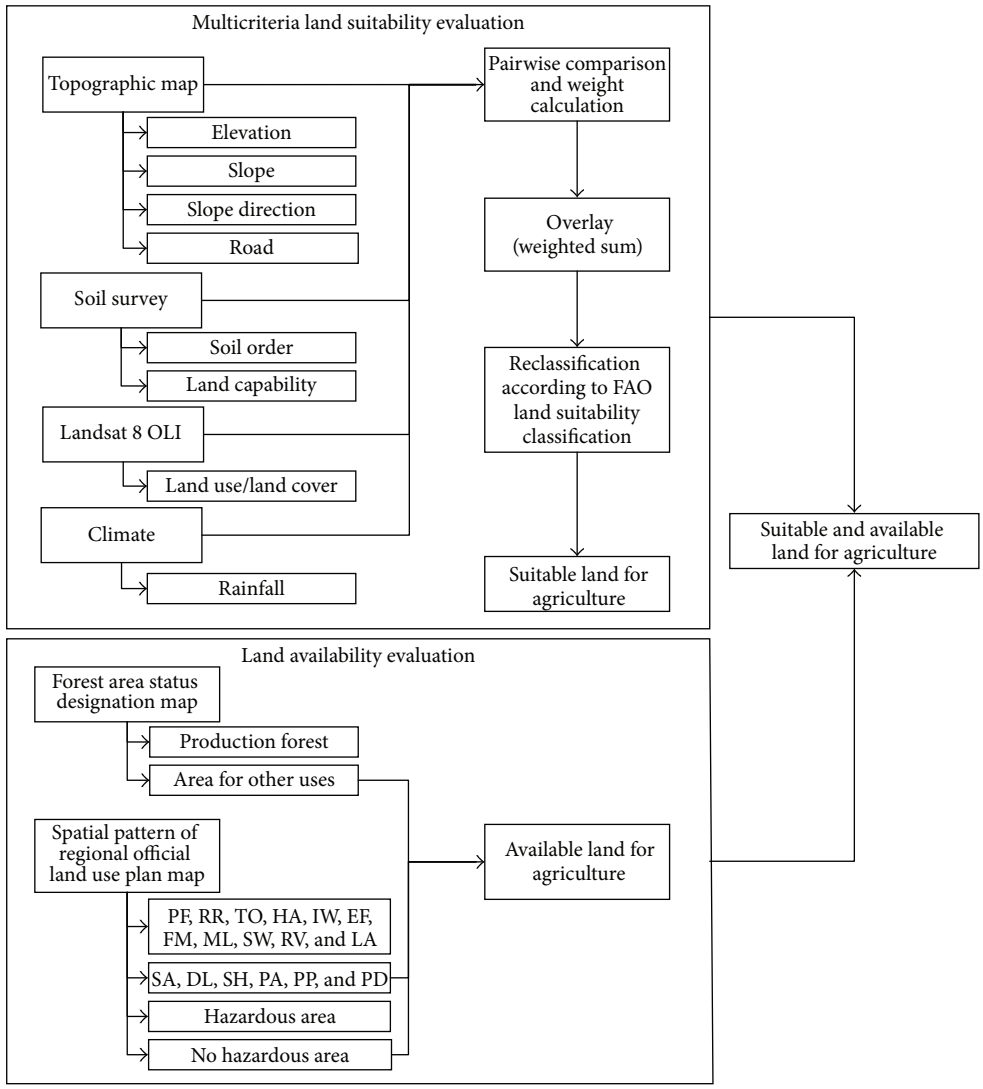

Figure 2: Procedure followed in generating suitable and available land for agriculture in Tuban Regency. Note: abbreviations used in spatial pattern of regional official land use plan (SP-ROLUP): PF: production forests, RR: reserved land for residential, PA: paddy fields, PP: paddy field/ponds, SA: sustainable agricultural land, DL: dryland farming, SH: shrub, TO: tourism, HA: harbour, IW: industry and warehouse, EP: electric power, FM: fish market, ML: mining land, SW: swamps, PD: ponds, RV: rivers, and LA: lake.

class data was derived from a soil survey in 2014, resulting soil map at scale of 1 : 25,000 [11, 20]. The map presents five soil orders [22]: Alfisols, Entisols, Inceptisols, Ultisols, and Vertisols (Figure 3(a) and Table 1). Inceptisols occupy the largest area, covering 83,152.9 ha (45.2% of the region). Alfisols are also quite widely spread, covering 41,967.5 ha (22.8%). The other soils, Entisols, Vertisols, and Ultisols, represent less than 15% of the study area each [11].

Land capability was classified according to the USDA's land capability classification [23]. The soil in Tuban Regency ranges from class II to class VIII (Figure 3(b) and Table 1). Areas with a land capability which supports agricultural uses (classes I–IV) make up 78.3% of the total land area, while the areas which should not be used for agricultural cultivation (classes V–VIII) made up 21.7% of the total land area [11].

Topographic Parameter. The topographic parameter included elevation, slope, and slope direction as criteria. All three criteria were taken from the Indonesian Topographic Map at a scale of 1 : 25,000, produced by the Indonesian Geospatial Information Agency [11]. Elevation, slope, and slope direction maps were made from this topographic map using the modules available in the ArcGIS 10.2 software (Figures 3(c), 3(d), and 3(e) and Table 1). According to slope, the dominant landform varies from undulating (3–8%), gently sloping (8–15%), and hilly (15–25%). This relates to elevation, which is dominated by three altitude classes, from 10 m to 500 m a.s.l. For slope direction, slopes facing north and south are dominant, followed by slopes facing east and west.

Ease of Management Parameter. Two criteria used were land use/land cover and accessibility. The land use/land cover

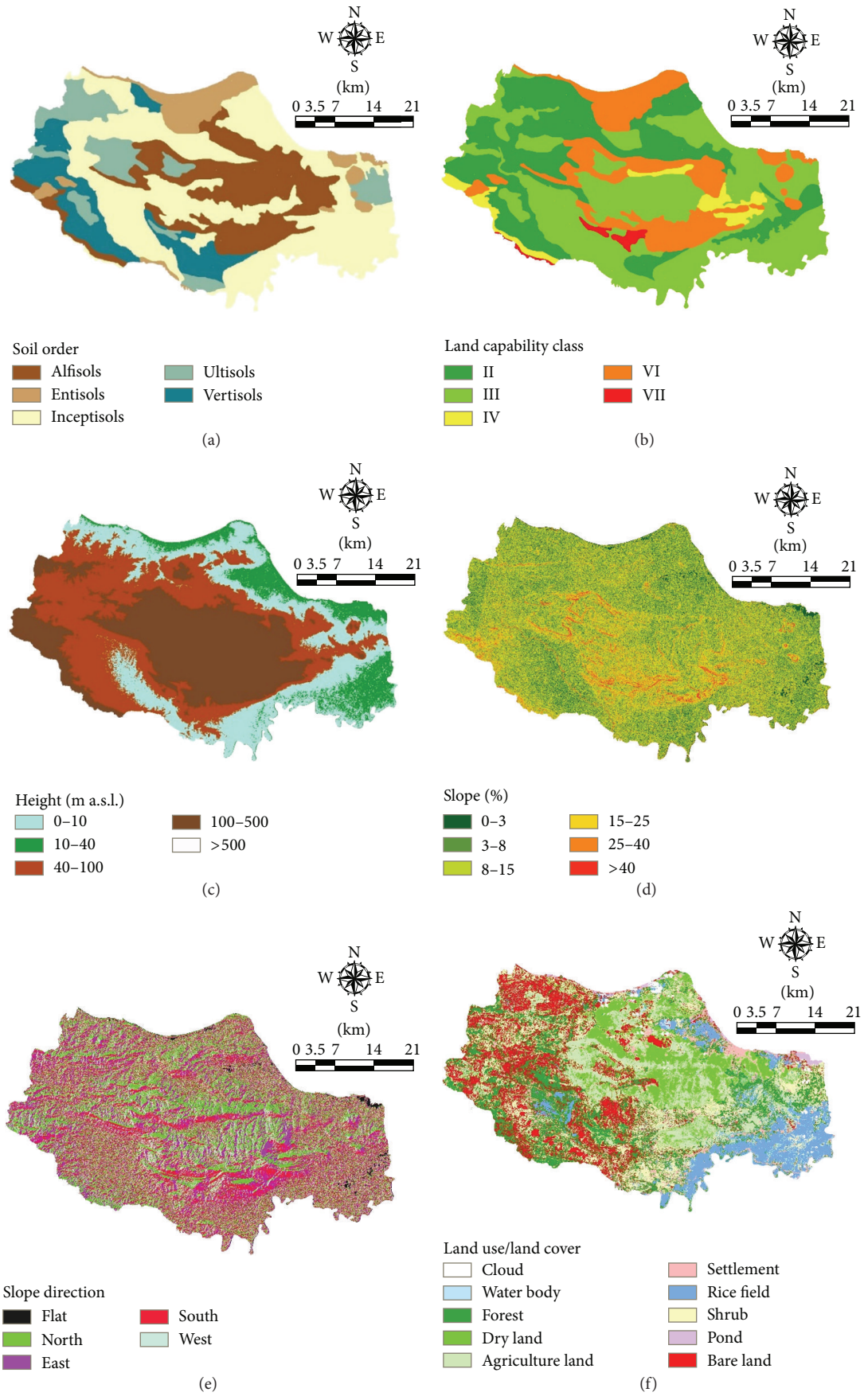

Figure 3: Continued.

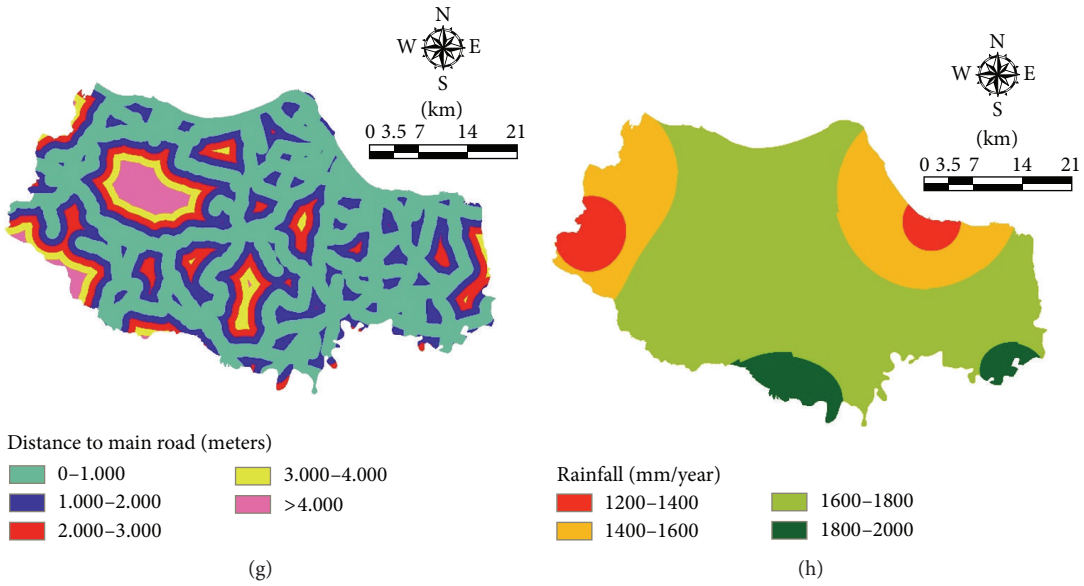

Figure 3: Criteria used for land suitability analysis in Tuban Regency: (a) soil order[1], (b) land capability class[1], (c) elevation[2], (d) slope[1,2], (e) slope direction[2], (f) land use/land cover[1], (g) distance to main road[2], and (h) rainfall[2] (source of figures: [1][11]; [2]analysis for this paper).

criteria were obtained from analysis using the Landsat 8 OLI imagery from the year 2013 [11] (Figure 3(f) and Table 1). Image interpretation was done by supervised classification using the ERDAS Imagine software, followed by field checks. Interpretation of the Landsat 8 OLI imagery produced 10 kinds of land use/land cover based on national standards classification [24]. The main land use/land cover in Tuban Regency regarding its area coverage are agricultural land, forest, open land, shrubs, and paddy fields. Dry land agriculture as well as residential areas occupies also a fairly wide area [11]. The accessibility was represented by the distance to a main road, obtained from the Indonesian Topographic Map of 1 : 25,000 (Figure 3(g) and Table 1).

Climatic Parameter. Climatic parameter considered in this study was the rainfall. Rainfall data were taken from interpolation of 35 rainfall stations in East Java Province, interpolated using geostatistical method. Spatial overlay with the administrative map of Tuban Regency was then done in order to obtain a rainfall map of Tuban Regency (Figure 3(h) and Table 1).

2.3.2. Weighting of Criteria and Scoring of Subcriteria

Weighting of Criteria. All of the spatial data were classified and weighted according to their contribution relative to agriculture to enable the creation of a suitability map for general agriculture (Figure 2). For weighting, expert consultation was conducted, for which eight experts were involved. Weighting was performed using AHP [25]. In this method, a pairwise comparison was done to obtain the relative importance of criteria considered. The ratings were derived from a nine-interest scale, with a value from 1 to 9 (Table 2) [7, 25].

Scoring. The scores were given according to the contribution of each subcriterion to agriculture; the score ranges from 0 to 10. High scores were given to the subcriteria that are considered the most important for agriculture, while low scores were given to the least influential subcriteria [6–8]. For some subcriteria, a score of 0 was given as a constraint, indicating that it is not suitable for agriculture. Scoring was done by experts' consensus.

2.3.3. Land Suitability Map. After the criteria weights and the subcriteria scores were appointed to the related layers in the ArcGIS 10.2 environment, raster maps were overlaid using the weighted sum overlay analysis and an agricultural land suitability map was generated. The weights of the criteria were multiplied with the score of the subcriteria; this multiplication was performed in raster format on the map. The result was then reclassified using equal distances as four classes of suitability [2]: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N), according to the following formula [7, 26]:

$$\mathrm{LS} = \sum_{i=1}^{n} w_i s_i, \tag{1}$$

where LS is land suitability; w_i is weight of land suitability criteria; s_i is score of subcriteria i; and n is number of land suitability classes.

2.4. Land Availability Evaluation. Two sets of spatial data were used for the land availability analysis: the spatial data from the FASD map at a scale of 1 : 250,000 (Figure 4(a)) [11, 12, 27] and the spatial data from SP-ROLUP map of Tuban Regency at a scale of 1 : 25,000 (Figure 4(c)) [11, 13]. In the FASD map, various states of forest areas are presented, including information about the different areas that allow for cultivation. The SP-ROLUP of Tuban Regency is an official document where land has been officially allocated

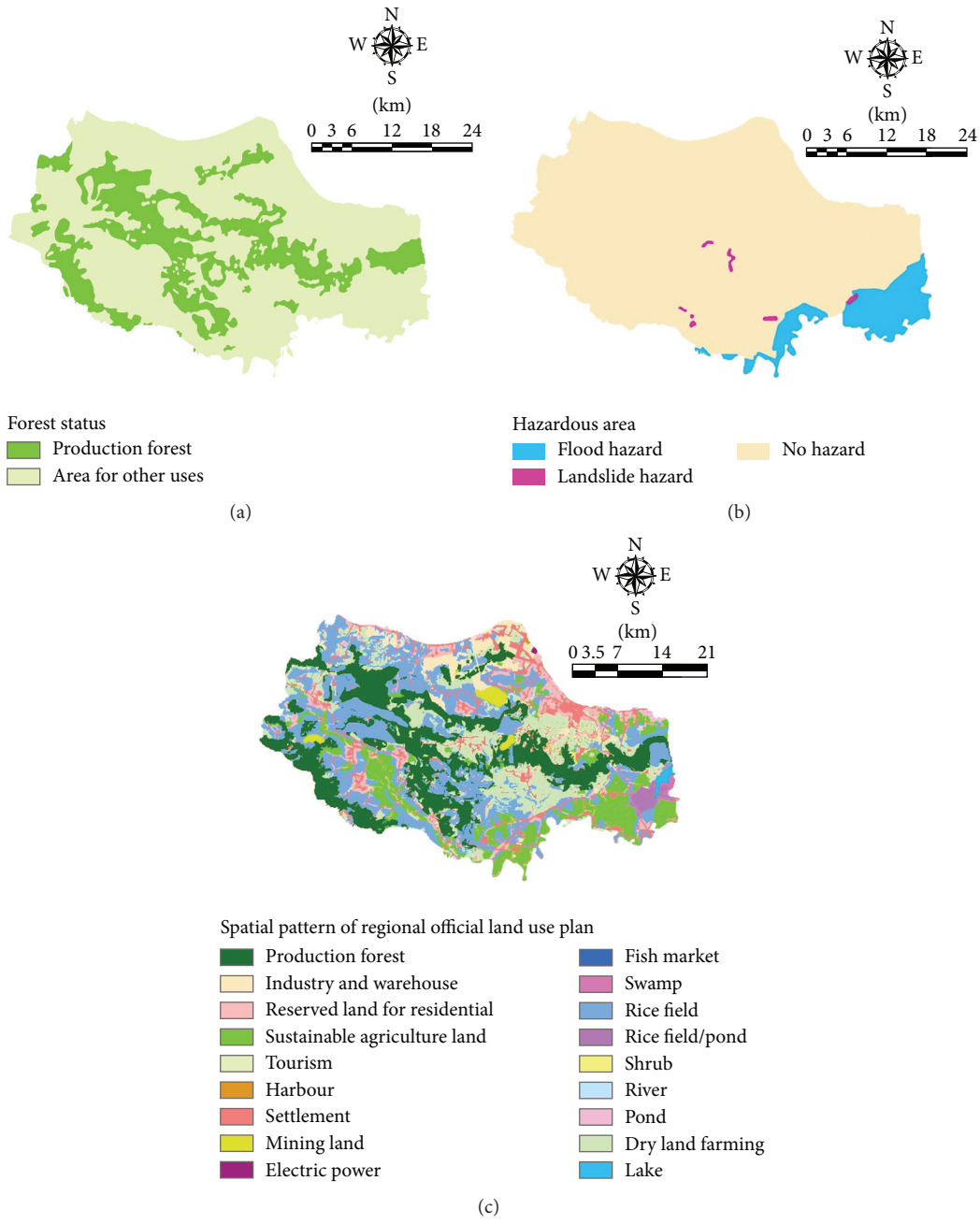

Figure 4: Maps used for analysis of land availability: (a) FASD map[1,3], (b) flood hazard and landslide hazard presented in SP-ROLUP[2], and (c) land allocation in SP-ROLUP map[2,3] (source of figures: [1][12]; [2][13]; [3][11]).

for different uses. From the SP-ROLUP map, the areas of flood hazard and landslide hazard (16,387.3 ha and 843.1 ha, resp.) [13] were also used as a constraint in the preparation of land availability map, assuming that areas with flood and landslide hazard are deemed as unavailable for agriculture (Figure 4(b)).

3. Results

3.1. Weights of Criteria and Scores of Subcriteria. The pairwise comparisons are presented so that the value of 9 indicates that the line is relatively more important than the column, while the value of one-ninth shows that the line has significantly less importance than the column (Table 3) [6, 20, 25, 28]. The results indicated that the consistency ratio (CR) was 0.04. This value was well within the ratio of being equal to or less than 0.10 [25].

The scoring of each subcriterion is shown in Table 4. When evaluating soil orders, a score of 10 was given to Inceptisols, which are soil which has a high natural fertility [22]. A score of 8 was given to Entisols which are young soils [22] that have a high fertility as well, but they are

Table 1: Distributions of the criteria and subcriteria in the study area of Tuban Regency.

Parameter	Criteria	Subcriteria	Area	
			ha	%
Land	Soil order[1]	Alfisols	41,967.5	22.8
		Entisols	15,364.6	8.4
		Inceptisols	83,152.9	45.2
		Ultisols	21,286.1	11.6
		Vertisols	22,223.6	12.1
	Land capability[1]	II	55,089.3	29.9
		III	81,601.8	44.4
		IV	7,862.5	4.3
		VI	37,269.8	20.3
		VIII	2,171.3	1.2
Topography	Elevation[2] (m a.s.l.)	0–10	18,872.2	10.3
		10–40	44,087.8	24.0
		40–100	61,829.0	33.6
		100–500	59,204.9	32.2
		>500	0.7	0.0
	Slope[1] (%)	0–3	16,882.3	9.2
		3–8	50,111.8	27.2
		8–15	68,115.5	37.0
		15–25	37,603.9	20.4
		25–40	9,296.6	5.1
		>40	1,984.6	1.1
	Slope direction[2]	Flat	2,270.8	1.2
		North	56,121.9	30.5
		East	39,109.1	21.3
		South	51,265.9	27.9
		West	35,227.0	19.2
Ease of management	Land use/land cover[1]	Cloud	2,190.1	1.2
		Water body	928.7	0.5
		Forest	36,648.3	19.9
		Dry land	19,489.6	10.6
		Agricultural land	37,908.5	20.6
		Settlement	11,140.4	6.1
		Paddy field	21,192.8	11.5
		Shrub	22,172.9	12.1
		Pond	941.2	0.5
		Bare land	31,382.1	17.1
	Distance[2] to road (m)	0–1,000	106,421.4	57.8
		1,000–2,000	44,862.7	24.4
		2,000–3,000	18,735.5	10.2
		3,000–4,000	7,800.5	4.2
		>4,000	6,174.5	3.4
Climate	Rainfall[2] (mm year^{-1})	1,200–1,400	10,168.7	5.5
		1,400–1,600	39,597.9	21.5
		1,600–1,800	124,159.0	67.5
		1,800–2,000	10,069.1	5.5
		Total	*183,994.6*	*100.0*

Data source: [1][11]; [2]analysis for this paper.

Table 2: Rating for pairwise comparison [7, 25].

1/9	1/7	1/5	1/3	1	3	5	7	9
Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very strong	Extreme
Less important					More important			

Table 3: A pairwise comparison matrix for assessing the weight (relative importance) of criteria for land suitability for agriculture in Tuban Regency.

	SO	LCC	ELE	SLP	SD	LU	DR	RF	Weight
SO	1	2	5	4	6	7	8	3	0.327
LCC	1/2	1	4	3	5	6	7	2	0.227
ELE	1/5	1/4	1	1/2	2	3	4	1/3	0.073
SLP	1/4	1/3	2	1	3	4	5	1/2	0.108
SD	1/6	1/5	1/2	1/3	1	2	3	1/4	0.050
LU	1/7	1/6	1/3	1/4	1/2	1	2	1/5	0.034
DR	1/8	1/7	1/4	1/5	1/3	1/2	1	1/6	0.024
RF	1/3	1/2	3	2	4	5	6	1	0.157

SO: soil order; LCC: land capability class; ELE: elevation; SLP: slope; SD: slope direction; LU: land use/land cover; DR: distance to road; RF: rainfall.
Max eigenvalue (γmax) = 8.422770477; $n = 8$; consistency index (Ci) = $(\gamma\text{max} - n)/(n - 1)$ = 0.060395782; random index (Ri) = 1.41; consistency ratio (Cr) = Ci/Ri = 0.042833888.

not mature enough and thus they can be considered less fertile than Inceptisols. A score of 6 was given to Vertisols, which are soils that have good chemical fertility but they are often constrained by poor physical properties with respect to their high clay content [22]. A score of 4 was given to Alfisols, old soils that have sufficiently high pH so that they have sufficiently high nutrient availability, while a score of 2 was given to Ultisols, which are old soils; they have acidity constraints and high exchangeable aluminium [22]. Agriculture is only permitted on land capability class I to class IV [23]; therefore, the highest to lowest scores were given to class I to IV land, and scores were 10, 8, 6, and 4, respectively. For land of class V and more a score of 0 was given; they become constraints because they are not permitted to be used for agriculture [11, 23].

For elevation, the lowlands are more desirable for agriculture and more suitable for the cultivation of various crops such as paddy; thus, a higher score was given. The higher the elevation, the lower the suitability for many crops, although of course there are still many plants that are more suitable at high altitudes. Slopes are very influential for agriculture. In terms of ease of processing and low erosion, flat land is better and so a score of 10 was given. According to Law number 26 of 2007 on Spatial Planning which is applicable in Indonesia, land with slopes >40% is protected and prohibited for agricultural uses, so a score of 0 was given. For slope direction, flat land and land facing east toward the rising sun are more suitable for agriculture, and so a high score was given to land with these slopes. Slope direction is associated with several properties, including exposure to sunlight, drying winds, and rainfall, which determine the different levels of suitability for agriculture.

In terms of actual land use/land cover, the highest score was given to actual agricultural land and paddy fields. For some land uses which are prohibited for agricultural use such as water bodies and settlements, a score of 0 was given as a constraint. The accessibility valuation was set by giving out higher scores to lands that were closer to the road; this was for reasons of ease of access, including better access to agricultural inputs and production transport [29]. The distance attributed was adapted according to the field conditions. It should be noted that there was no area that was given a score of 0 because almost all areas in Java Island are relatively accessible.

In terms of rainfall, a higher score was given to high intensity rainfall due to its implication for water sufficiency for agriculture. In this region, the whole climate range remained suitable for agriculture; therefore, no extreme scores were given, because of either too high or too low rainfall intensity.

3.2. Land Suitability. Of the whole Tuban Regency, most of the area is suitable for agriculture (Figure 5 and Table 5). The suitable land for agriculture in the region includes 166,916.3 ha or 90.7% of the entire area of the regency which is 183,994.6 ha. Of this suitable land, the majority (33.1%) is land that is highly suitable (S1) for agriculture. There is only 9.3% of the area of the region where land was classified as not suitable for agriculture.

3.3. Suitable Land Available according to Forest Area Status Designation (FASD). In Indonesia, the land utilization for any cultivation is restricted by Law number 41/1999 on Forestry. Land utilization for cultivation (residential, industrial, and others, including agriculture) can only be done outside the FASD, in the so-called area for other uses (AOU). Based on the FASD, Tuban Regency area can be classified into two classes, namely, production forest area and AOU. Production forest areas occupy an area of 51,995 ha, which represents 26.5% of the entire study area, while the other 74.5% has the status of AOU. Overlaying the land suitability

Table 4: Scores of the subcriteria used in Tuban Regency.

Parameter	Criteria	Weight	Subcriteria	Score
Land	Soil order	0.327	Inceptisol	10
			Entisol	8
			Vertisol	6
			Alfisol	4
			Ultisol	2
	LCC	0.227	I	10
			II	8
			III	6
			IV	4
			V–VIII	0
Topographic	Elevation	0.073	0–10	10
			10–40	8
			40–100	6
			100–500	4
			500–2,000	2
			>2,000	0
	Slope	0.108	0–3	10
			3–8	8
			8–15	6
			15–25	4
			25–40	2
			>40	0
	Slope direction	0.050	Flat, east	10
			West	8
			North	6
			South	4
Ease of management	Land use/land cover	0.034	Agricultural land, paddy field	10
			Dry land	8
			Bare land	6
			Shrub	4
			Forest	2
			Cloud, water body, settlement, pond	0
	Infrastructure	0.024	0–1,000	10
			1,000–2,000	8
			2,000–3,000	6
			3,000–4,000	4
			>4,000	2
Climate	Rainfall	0.157	1,200–1,400	4
			1,400–1,600	6
			1,600–1,800	8
			1,800–2,000	10
Total		*1.000*		

map with map of FASD leaves an area of 155,527 ha (84.6%) which is suitable for agriculture at any different suitability (S1 to S3) outside FASD (Figure 6(a) and Table 6). The unsuitable land outside FASD was 16,988.7 ha. An area of 11,479 ha was so unavailable for agriculture because it was inside FASD, regardless of its suitability.

3.4. Suitable Land Available according to Spatial Pattern of Regional Official Land Use Plan (SP-ROLUP). Land use planning in Indonesia should conform to Law number 26 of 2007 on Spatial Planning. Spatial land allocation of Tuban Regency consists of land for production forests, reserved land for residential, paddy fields, sustainable agriculture,

Table 5: Distribution area of suitable land for agriculture in Tuban Regency.

Suitability level	Total area classified by the suitability analysis	
	ha	%
Highly suitable	60,812.3	33.1
Moderately suitable	53,866.8	29.3
Marginally suitable	52,237.2	28.4
Not suitable	17,078.3	9.3
Total	*183,994.6*	*100.0*

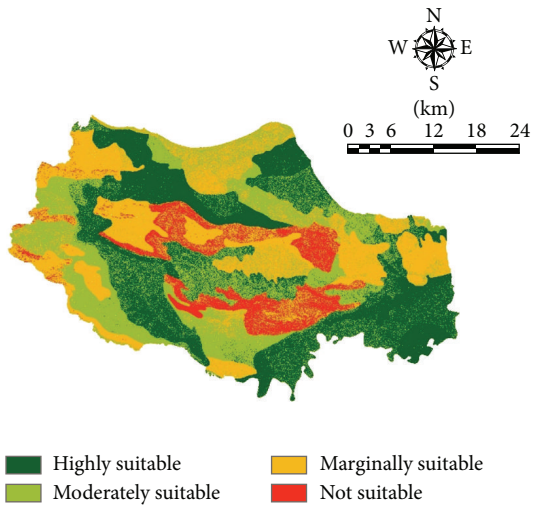

Figure 5: Suitable land for agriculture in Tuban Regency.

tourism, housing, industry and warehouse, plantation, fish landing centres, ports, mines, swamps, ponds, and rivers. Of the allocation in the SP-ROLUP, land which is available for agriculture includes sustainable agricultural land, paddy fields, and ponds. Calculating, from the 183,994.6 ha of study area, the land which is available for agricultural use according to SP-ROLUP (i.e., inside the area permitted for agriculture use) and free from flood and landslide hazards, 34,496 ha or 18.7% of the total area is found (Figure 6(b) and Table 6), while 16,988.7 ha is not available.

3.5. Final Suitable and Available Land for Agriculture. The overlay done between the FASD-based suitability map and the SP-ROLUP-based suitability map gives the suitable land which is available for agriculture. The final results showed that the total area of suitable land which is available for agriculture was 33,385.3 ha or 18.2% of the total study area. This comprises 6.4% of highly suitable land, 5.4% of moderately suitable land, and 6.4% of marginally suitable land (Figure 7 and Table 6).

4. Discussion

The results of the analysis showed that the unsuitable area corresponds with high slopes falling under land capability class V or more. Our results which indicate the high percentage of suitable land for agriculture in Tuban Regency confirm the known fact [30] that the study area has fertile soil.

The results of the analysis showed that the area which is suitable and available for agriculture remains 18.2%. In the context of SP-ROLUP, it is logical that some of the land had to be allocated to the various needs, as agriculture is just one of the various land utilizations. Regarding the analysis results in this regency, it can be stated that the suitable lands which are available for agriculture are not many. In the context of the country, this fact was also found in other areas in Java Island [7, 14]. It is so becoming somewhat ironic and even worrying that the availability of food in the country with the fourth largest population in the world depends on an island that constitutes less than 7% of the state territory, of which less than a fifth is suitable and available for agriculture.

For the case of Tuban Regency, a more detailed analysis can be conducted by viewing the suitable and available land which is actually being used for agriculture. Based on the data of land use/land cover resulting from imagery interpretation and field survey results (Table 1), it can be stated that the land use/land cover that has actually been used for agriculture consists of paddy fields (an area of 21,192.8 ha), agricultural land (an area of 37,908.5 ha), and ponds (an area of 941.2 ha). This agricultural land includes state plantations, smallholdings plantations, and ponds that are permanent land utilization. Overlaying the suitable and available land results from the final analysis with land actually used for agriculture leaves 11,123.2 ha or 6.7% of the total suitable and available land area for agriculture. This area constitutes the possibility for agricultural expansion when necessary. This expansion possibility constitutes a very small area considering the rapid growth of the population with its need for food as well as infrastructure.

These results reveal that there is no longer as much land available in the region which can be used for the development of agriculture, although the area has the fertile and suitable soil for agriculture. The expansion of paddy fields, for example, which is absolutely necessary because of the increasing population and its implications for increasing food demand, seems to be hard to accomplish. The implication is that the search for productive land outside Java Island is imperative.

This research is also intended to provide broader awareness to the stakeholders and policymakers in the country where the situation of land utilization in Java Island is completely serious. Although many parties claim to be aware of this situation, in reality many controversial policies continue to be enacted. An example is the policy actually applicable in Indonesia [31]. In this policy, the development of Indonesia is divided into six corridors of development, one of which is a corridor of Java Island whose main policy direction is to make Java Island the centre of industry and national services. Seeing that there is still a very high dependence in Indonesian food supply on the island of Java today, this policy is feared to accelerate the conversion of agricultural land into industrial land. The implication is the danger of food insecurity of Indonesia in the medium- and long-term, given that the development of the agricultural sector outside Java Island will still take time. Corrections to several current

Table 6: Distribution area of suitable land which is available for agriculture in Tuban Regency.

Suitability level	Taking into account FASD[1]		Taking into account SP-ROLUP[2]		Taking into account FASD and SP-ROLUP[3]	
	ha	%	ha	%	ha	%
Highly suitable	59,350.0	32.3	12,019.7	6.5	11,764.4	6.4
Moderately suitable	48,866.2	26.6	10,388.0	5.6	9,898.0	5.4
Marginally suitable	47,310.8	25.7	12,088.3	6.6	11,722.9	6.4
Not suitable	16,988.7	9.2	16,988.7	9.2	16,988.7	9.2
Not available	11,479.0	6.2	132,509.9	72.0	133,620.6	72.6
Total	*183,994.6*	*100.0*	*183,994.6*	*100.0*	*183,994.6*	*100.0*

[1]The suitability was measured only for the area outside the forest area status designation (FASD), while the area inside the FASD is considered as unavailable.
[2]The suitability was measured inside the area permitted for agriculture (outside the area not permitted for agriculture, which is considered as unavailable) according to spatial pattern of regional official land use plan (SP-ROLUP) map.
[3]Combination of 1 and 2.

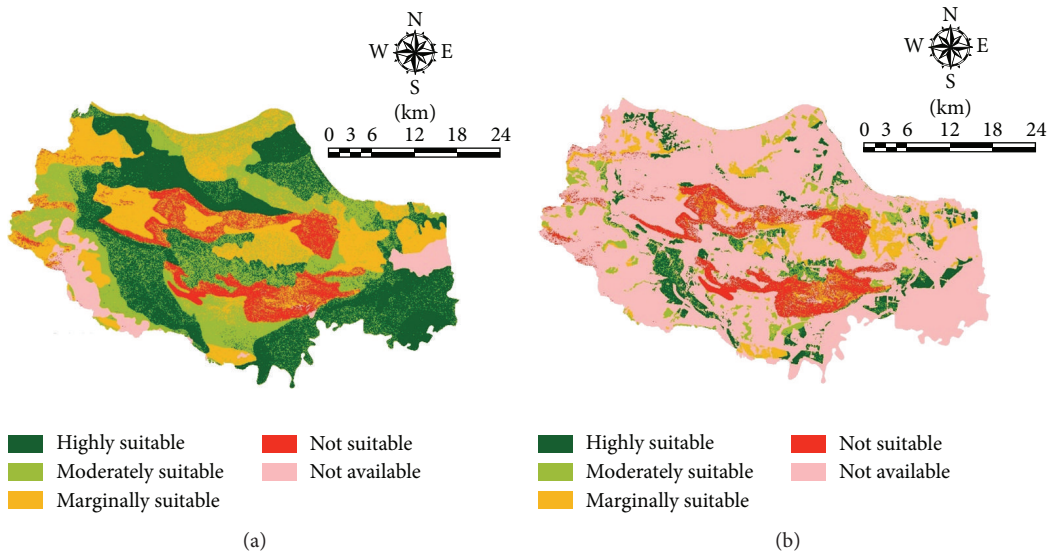

Figure 6: Land in Tuban Regency which is both suitable and available for agriculture, taking into account (a) FASD and (b) SP-ROLUP.

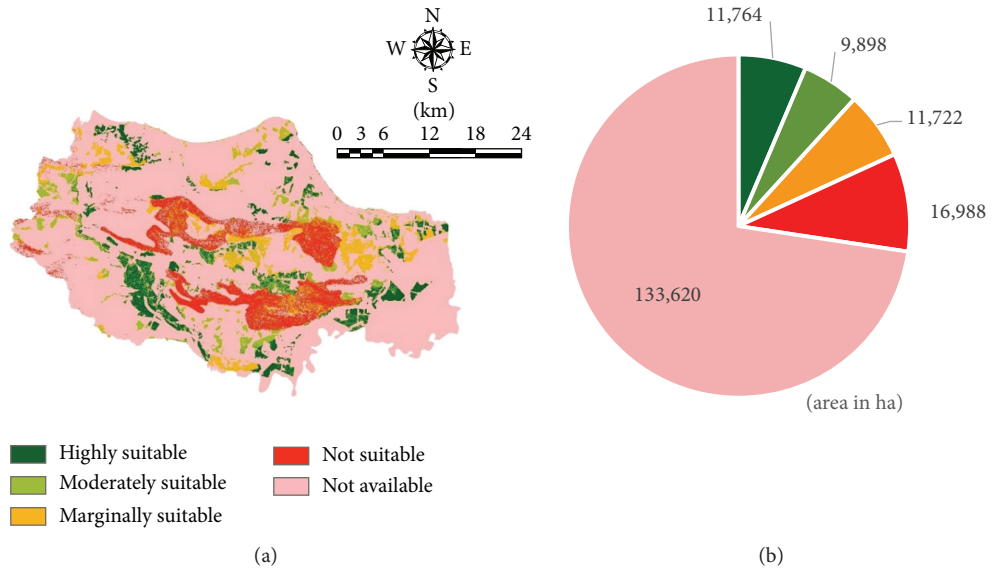

Figure 7: Final map (a) and total area (b) of land which is suitable and available for agriculture in Tuban Regency when considering constraints from FASD and SP-ROLUP.

government policies might be necessary in order to ensure future food security.

The necessity of taking into account the FASD map can be viewed from an environmental protection perspective. Although a large proportion of the land is suitable for agriculture, the area inside the FASD should not be used for agriculture. This regulation is necessary in order for Indonesian forests to remain sustainable [20, 32]. As is known, Indonesian forests are one of the largest and most biodiverse tracts of tropical rainforest in the world, hosting mega-biodiversity comparable to that of the Amazon in Brazil. In the context of environmental sustainability, land use planning for agriculture needs to follow regulations.

There are some limitations to the validity of this analysis which should be noted. Firstly, from the point of view of the methodology, the suitability analysis depended on the AHP result, which is highly dependent on experts' opinions. AHP has the advantages of decomposing issues so that complex problems can be structured; nevertheless, by its nature AHP is highly dependent on experts and as a result it is very subjective. Competent experts have been chosen for this study, and the AHP results have the consistency ratio required to be valid. Nevertheless, the subjective character of the method still needs to be noted. The second limitation to the validity of this suitability analysis lies on how the parameter and criteria are viewed upon. In reality, land suitability for agriculture should also consider social aspects. In this study, the social aspect is accommodated within the parameters of ease of management, which included criteria such as land use/land cover and distance from the road. However, there were many other aspects which should also be considered, such as labor availability. One of the obstacles to integrate more social aspects in this type of study is the difficulty in which to integrate social aspects into spatial representation. Consequently, other social aspects that are not explored during this study should be considered in further and other types of studies.

5. Conclusion

The analysis in this study showed the suitable land which is available for agriculture in a regency in Java Island, Indonesia's most fertile island. Land suitability analysis was conducted by integrating the main influential parameters for agriculture, which include soil class, land capability class, slope, elevation, slope direction, present land use, distance to road, and climate. Integration using MCA produced suitable land corresponding to 90.7% of the total land area in Tuban Regency. Analysis of the land availability then indicated that 18.2% of the area is suitable and available for agriculture. When considering the suitable land which is now used for agriculture, the development of agriculture in the region has only 6.7% of the land area in which to expand. The results of this analysis show the importance of seeking the allocation of land outside Java Island to anticipate the need for food in the area with a high population growth rate, as well as the development of policy in favour of agricultural development.

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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