ABSTRACT

The hinterland of Jakarta has experienced high pressure in its land utilization due to Jakarta’s rapid urban development. The objective of this study is to analyze the suitable land available for general agriculture. The research was conducted in Bogor Regency, West Java, a hinterland regency of Jakarta. The methodology used includes 2 (two) steps of analysis, which are land suitability analysis and land availability analysis. Land suitability for agriculture was analyzed using the method of multi-criteria decision making. Seven (7) criteria were included, and each criterion consisted of further sub-criteria. The criteria were weighted using the Analytical Hierarchy Process, while the sub-criteria were scored by expert judgement. Combining criteria and sub-criteria, a weighted overlay model in Geographic Information System was then applied. The result from the land suitability analysis was used as a feed for determining land availability by considering the forest area status and land allocation in the official spatial land use plan. The results of the study indicate that according to land suitability analysis, an area amounting to 87.5% of Bogor Regency is suitable for agriculture. By integrating the forest area status and the official spatial land use plan, land which is suitable and available for agriculture is 16.7% of the regency’s area. Considering available land which is currently in use, the area that can be allocated for the expansion of agriculture is only 3.3%, delineated spatially in this research.

Keywords: Land suitability; land availability; soil order; land capability; land use planning

INTRODUCTION

The state capital of Indonesia, Jakarta, has been developing very rapidly to become the second largest metropolitan area in the world after Tokyo (Fukami et al., 2014; Pravitasari et al., 2015). Data on the period from 1972 until 2010, for example, indicate that the urban area of Jakarta and its surroundings, namely the Jakarta-Bogor-Depok-Tangerang-Bekasi (Jabodetabek) region have increased by more than 2,096 km², as a result of urbanization processes (Rustiadi et al., 2013;
Pravitasari et al., 2015). The pace of development of Jakarta has induced rapid land use changes in the surrounding area. The surrounding region, which was an agricultural region with regencies such as Tangerang, Bekasi and Bogor forming the agricultural hinterland, has experienced the pressure of Jakarta’s development through the development of urban areas that are often random sprawl (Hidajat et al., 2013). In this area, urbanization and suburbanization are expanding mainly by the conversion of agricultural land (Rustiadi & Panuju, 2002). One of the implications is the increase in the industrial, residential and built area as well as the decrease in agricultural land. Statistical data show that despite the extent of paddy field in Bogor which was relatively constant at around 47,500 ha, dry land agriculture has been reduced from 142,764 ha in 2002 (Statistics West Java, 2003) to 127,369 ha in 2013 (Statistics West Java, 2014, data processed). In the same period, yards, buildings and built area in Bogor Regency has increased from 37,020 ha (Statistics West Java, 2003) to 92,294 ha (Statistics West Java, 2014, data processed).

Such a situation indicates the high pressure on land utilization in Bogor Regency, including on agricultural land. Similar phenomena seem also to have occurred in the hinterland of other metropolitan cities on the island of Java, an island which makes up only 7% of the land area of Indonesia (Statistics Indonesia, 2014a), but is inhabited by more than 50% of Indonesia’s population (Statistics Indonesia, 2014a). In fact, in current conditions and at least for the next few years, Indonesian agriculture will still be highly dependent on the availability of land in Java Island, given that agricultural development outside of Java Island is relatively slow (Widiatmaka et al., 2015a).

Addressing the increasing pressure on agricultural land, one of the measures that can be taken – other than finding alternative agricultural land outside the island of Java – is using agricultural land available on Java Island in a more efficient way. This is unavoidable, given that the actual base of food production, and this is true both in the immediate short to medium term and in the future, will remain on Java Island. To illustrate the situation, in 2013, 52% of the domestic paddy yield as well as 53% of corn, 65% of soybean and 70% of green bean came from Java Island (Statistics Indonesia, 2014b, data processed). One of the questions which can be raised is therefore, how much area can actually still be used for agriculture in Java? Which areas of land should be used in a more efficient way? This research conducted in Bogor Regency will analyze the situation in its local conditions.

One way to improve land utilization efficiency in agriculture is by using land with high suitability. More detailed analysis for specific commodities can then be carried out afterwards. Land evaluation is
the first step towards land use planning (Roetter et al., 2005; Widiatmaka et al., 2014a), with the aim
of delineating land at various levels of suitability.

Since the introduction of the land evaluation concept (FAO, 1976) that considers physical,
social and economic aspects of land resources (Akinci et al.; 2013; Widiatmaka et al., 2015b), this
concept has been developed rapidly. Various tools have been developed, including the Land
Evaluation Computerized System (LECS) (Wood & Dent, 1983), the Comprehensive Resource
Inventory and Evaluation System (CRIES) (Chidley et al., 1993), the Automated Land Evaluation
System (ALES) (Rossiter, 1990), the ELimitation Et Choix Traduisant la Réalité (ELECTRE-Tri)
(Mendas & Delali, 2012) and the Agriculture Land Suitability Evaluator (ALSE) (Elsheikh et al., 2013)
to mention some examples. The methodology developed includes the integration of hard system
methodology (Lustig, 1998) including the integration of dynamic system modelling in land evaluation
(Widiatmaka et al., 2014b), as well as soft system methodology for decision making (Lustig, 1998;
Cengiz & Akbulak, 2009). The soft system methodology for decision making has been developed
using tools for multi-criteria decision-making, among others the Analytical Hierarchy Process (Saaty,
1994; Rahman & Saha, 2008) and more recently, the Analytical Network Process (Saaty & Vargas,
2006; Aragonés-Beltrán et al., 2014; Zabihi et al., 2015). This development is supported by the rapid
development in remote sensing and geographic information systems (Malczewski, 2006). This has
allowed the land evaluation method to be achieved through the decision-making concept utilizing
several criteria which can be done spatially. The concept is not only useful for agriculture (Baja et al.,
2007; Bandhyopadhyay et al., 2009), but it is also used for other sectors including forestry, industry,
tourism, environment and energy (Geneletti, 2004; Guiqin et al., 2009; Effat & Hegazy, 2012; Zucca et
al., 2012; Rikalovic et al., 2014; Segura et al., 2014).

Apart from carrying out analysis to select suitable land, land availability also needs to be
analyzed in view of the need for land by other sectors. In the Indonesian context, the forest area has
been formally defined in the Forest Area Status (FAS) map, where the use of land for farming can
only be undertaken in land outside the forest area, defined as “area for other utilization” (AOU)
(Ministry of Forestry, 2003). This regulation is intended to maintain the sustainability of forest cover for
ecosystem sustainability (Kusmana, 2011). Land allocation was also formally arranged through formal
allocation by the Official Spatial Land Use Plan (OSLUP) (Government of Indonesia, 2007), where
land was allocated for many sectors. Consideration of such regulations can be achieved through the
integrated analysis of land suitability and land availability (Widiatmaka et al., 2015b). In such a manner, land use planning for agriculture can be achieved in the context of land utilization for other sectors. Selection of land through the integration of land suitability and land availability will also be useful in keeping land utilization sustainable. The objective of this paper is, therefore, to delineate land suitability for agriculture and then to delineate such suitable land which is also available for agriculture.

MATERIALS AND METHODS

Study Area. The study was conducted during 2015 in Bogor Regency; the study area was chosen in this research as a case study of land with high pressure land utilization considering its proximity to the capital urban area (Figure 1). This regency has an area of 2,301.95 km², or approximately 5.19% of the area of West Java Province (Statistics Bogor Regency, 2014). The research area lies in the geographical position of 6°19'-6°47' South and 106°1'-107°103' East. The average annual rainfall is 3,992.7 mm. The wettest month is January, with an average monthly rainfall of 509.2 mm, while the driest month is June, with an average monthly rainfall of 62.3 mm. The average air temperature in 2013 ranged from 25.1°C to 26.4°C. The hottest air temperature occurred in June, amounting to 34.7°C, while the coldest was in December at 19.0°C. The landforms of the region are diverse, predominantly flat in the north part, while the southern part is dominated by undulating to mountainous landforms (Statistics Bogor Regency, 2014).

Data. The spatial data for soil classification are compiled from the results of previous mapping (Atmosentono, 1968; CSR, 1981; CSAR, 1992; Widiatmaka et al., 2015c), done at a scale of 1:50,000. Although on the original map, soils were classified in more detailed classifications, in this paper soil classification was presented in soil order category only (USDA, 2010). Data from these previous research studies are also used in this study for the creation of a land capability map according to the criteria of Klingebiel and Montgomery (1961), modified in a more quantitative way by Arsyad (2010). Topographic maps from the Indonesian Geospatial Information Agency at a scale of 1:25,000 were used for the creation of spatial data on elevation, slope and slope aspect using the spatial module of ArcGIS 10.2 (Widiatmaka et al., 2015c). The data on the distance from the road were created by buffering the 1st and 2nd order road on such topographical maps. The actual land utilization was interpreted from Landsat OLI of 2013, interpreted in this research by supervised
classification using ERDAS Imagine software (Widiatmaka et al., 2015). The Indonesian standard imagery classification (SNI, 2010) was used. Field checking was done during August 2015.

Figure 1. Research area of Bogor Regency, West Java

Analysis. The analysis of land suitability and land availability for agriculture was carried out sequentially. Land suitability analysis was first performed using the method of multi-criteria decision making. In this procedure, an analytical hierarchy process (AHP) was carried out to obtain the weighting of criteria. The criteria consist of several parameters which are considered influential for land suitability. The criteria used can be grouped into 3 (three) parameters: (i) parameters of soil and land, (ii) topographic parameters, and (iii) land management parameters. The parameters of soil and land include soil class and land capability class; the parameters of topography include slope, elevation and slope aspect; while the parameters of land management include distance from the road and the actual land use/land cover. Each criterion consists of sub-criteria. The spatial data for criteria and sub-criteria were presented in Figure 2, while their quantitative distributions were presented in Table 1 (columns d-e). The AHP was conducted, involving 7 (seven) experts. In practice, this process used pairwise comparisons of Saaty’s AHP concept. Each pair of criteria were assessed for their importance from 1 to 9 (Saaty, 1994) (Table 2). The result of this process is said to be valid if the consistency ratio (CR) is less than 10% (Saaty, 1994).
Figure 2. Spatial distribution of: a. soil order; b. land capability class; c. elevation; d. slope; e. slope aspect; f. land use and land cover; g. distance from road. Data sources: 1. Compiled and processed from Atmosentono (1968), CSR (1981); CSAR (1992); 2. Widiatmaka et al. (2015c); 3. Spatial treatment from Geospatial Information Agency’s topographic map of 1:25,000; 4. Interpreted from Landsat OLI of 2013.

The sub-criteria were scored in accordance with the degree of contribution of each sub-criterion to land suitability for agriculture; such scoring was done with consideration of the experts’ judgements. The scores given for each sub-criterion were presented in Table 1 (column f). For the criteria of soil order, the weight given is 10 for the sub-criterion of Mollisols, 8 for Inceptisols, 6 for Andisols, Vertisols and Entisols, while for Ultisols, the score of 4 was given. The highest score was given to Mollisols because they have good properties chemically. To Inceptisols, sufficiently high scores were given because this soil was considered suitable for agriculture, it is a relatively young soil but having high natural fertility (USDA, 2010). To the Andisols, Vertisols and Entisols the same score of 6 were given. The Ultisols are considered to have the lowest suitability for agriculture due to...
several barriers such as high exchangeable Aluminium (Heim et al., 2003; Ward et al., 2010) and an argillic horizon (USDA, 2010) that constitutes a chemical and physical barrier for root penetration (Moncharoen et al., 2001).

For land capability class, the sub-criterion of land capability class V or lower was scored 0 because land with such classes cannot be used for agriculture (Klingebiel & Montgomery, 1961), while land with land capability classes I to IV were scored sequentially as 10, 8, 6 and 4. For altitude, land at low altitude is considered more suitable for more crops. Land at an altitude of more than 2000 m is not permitted for agricultural use (Government of Indonesia, 2007), so it is given a score of 0. For criteria of slope, a slope of more than 40% was scored 0 because it is not permitted for agriculture (Government of Indonesia, 2007), while other slopes are scored in a sequence of 10, 8, 6, 4 and 2 parting from flat land.

In the case of slope aspect, flat land and land with a slope facing to east were given the highest score of 10 as an optimal surface to the sun, considered optimal for physiological activities (Akinci et al., 2013). The other slope aspects were scored successively according to their direction towards the sun.

In terms of land use and land cover, land utilization which is not possible for agriculture such as settlements and the airport were scored at 0, while higher scores were given to existing agricultural land. In terms of distance to roads, land that lies closer to the road is considered more suitable for reasons of market access.

Table 1. Distributions of the criteria, and sub-criteria in the study area

| Parameter  | Criteria          | Sub Criteria | Area (a) | % (b) | Score (c) |
|------------|-------------------|--------------|----------|-------|-----------|
| Land Soil Order | Mollisols         | 7,625.8      | 2.6      | 10    |
|             | Inceptisols       | 171,698.0    | 57.5     | 8     |
|             | Andisols          | 23,655.3     | 7.9      | 6     |
|             | Entisols          | 24,773.2     | 8.3      | 6     |
|             | Ultisols          | 55,071.6     | 18.4     | 4     |
| Land Capability | III               | 64,569.0     | 21.6     | 6     |
|             | IV                | 81,515.9     | 27.3     | 4     |
|             | VI                | 72,689.5     | 24.3     | 0     |
|             | VII               | 70,071.4     | 25.5     | 0     |
|             | VIII              | 3,879.6      | 1.3      | 0     |
| Topography Elevation | <40              | 2,017.6      | 0.7      | 10    |
|             | 40–100            | 58,693.7     | 19.6     | 6     |
|             | 100–500           | 141,511.9    | 47.4     | 4     |
|             | 500–2000          | 95,819.2     | 32.1     | 2     |
|             | >2000             | 795.9        | 0.3      | 0     |
| Slope | 0–3                | 21,137.1     | 7.1      | 10    |
|         | 3–8                | 67,457.7     | 22.6     | 8     |
|         | 8–15               | 74,250.7     | 24.8     | 6     |
|         | 15–25              | 58,628.4     | 19.6     | 4     |
### Table 2. Rating for pairwise comparison according to Saaty (1994)

| Parameter | Criteria | Sub Criteria | Area (ha) | Score |
|-----------|----------|--------------|-----------|-------|
| (a)       | (b)      | (c)          | (d)       | (e)   | (f)   |
| 25 – 40   | 42,693.1 | 14.3         | 2         |
| >40       | 34,671.4 | 11.6         | 0         |
| Aspect²   | Flat     | 553.3        | 0.2       | 10    |
|           | East     | 36,193.7     | 12.1      | 10    |
|           | North-East| 44,732.1     | 15.0      | 8     |
|           | South-east| 30,630.7     | 10.2      | 8     |
|           | West     | 36,364.5     | 12.2      | 8     |
|           | North-West| 42,605.4     | 14.3      | 6     |
|           | South-West| 30,026.3     | 10.0      | 6     |
|           | North    | 50,575.2     | 16.9      | 4     |
|           | South    | 27,157.3     | 9.1       | 4     |
| Land Manag.| Land Use¹| Dryland agriculture | 83,042.3 | 27.8  | 10    |
|           |          | Paddy field  | 58,608.6 | 19.6  | 10    |
|           |          | Plantation   | 14,068.7 | 4.7   | 10    |
|           |          | Dryland mixed agriculture | 39,649.3 | 13.3  | 8     |
|           |          | Primary dryland forest | 1,354.4 | 0.5   | 8     |
|           |          | Secondary dryland forest | 32,347.2 | 10.8  | 8     |
|           |          | Plantation forest | 24,322.1 | 8.1   | 8     |
|           |          | Bared land   | 745.0     | 0.2   | 6     |
|           |          | Shrub        | 2,375.8   | 0.8   | 4     |
|           |          | Airport      | 69.8      | 0.0   | 0     |
|           |          | Mining       | 666.0     | 0.2   | 0     |
|           |          | Water body   | 862.1     | 0.3   | 0     |
| Distance²| 0-1,000  | 228,183.8    | 76.4      | 10    |
|           | 1,000-2,000 | 45,489.1   | 15.2      | 8     |
|           | 2,000-3,000| 16,376.9    | 5.5       | 6     |
|           | 3,000-4,000| 6,593.6     | 2.2       | 4     |
|           | >4,000   | 2,194.9      | 0.7       | 2     |
| Total     | 183,994.6| 100.0        |           |       |

Data Source: see Figure 2.

The land suitability map is created by multiplying the weight of criteria and score of sub-criteria. The suitability was then divided into four classes: highly suitable, suitable, marginally suitable and not suitable (FAO, 1976) by dividing into equal quartiles, according to the equation below (Rahman & Saha, 2008; Cengiz & Akbulak, 2009):

\[ S = \sum_{i=1}^{n} w_i x_i \]

where: \( S \) = land suitability; \( w_i \) = weight of land suitability criteria; \( x_i \) = score of sub-criteria \( i \); \( n \) = number of land suitability criteria

**RESULTS AND DISCUSSION**
The results of pairwise comparisons are summarized in Table 3. Such a result is considered to be valid as indicated by a value of CR less than the threshold of 0.1. This value indicates that the decision was not given by chance (Saaty, 1994).

Table 3. Weight of parameter resulting from pairwise comparison of criteria

|     | SO   | LCC | EL  | SL  | SA  | LULC | DR  | Weight |
|-----|------|-----|-----|-----|-----|------|-----|--------|
| SO  | 1    | 2   | 5   | 3   | 9   | 4    | 7   | 0.362  |
| LCC | 1/2  | 1   | 4   | 2   | 7   | 3    | 5   | 0.238  |
| EL  | 1/5  | 1/4 | 1   | 1/3 | 3   | 1/2  | 2   | 0.068  |
| SL  | 1/3  | 1/2 | 3   | 1   | 5   | 2    | 4   | 0.156  |
| SA  | 1/9  | 1/7 | 1/3 | 1/5 | 1   | 1/4  | 1/2 | 0.029  |
| LULC| 1/4  | 1/3 | 2   | ½   | 4   | 1    | 3   | 0.103  |
| DR  | 1/7  | 1/5 | 1/2 | ¼   | 2   | 1/3  | 1   | 0.044  |

Note: SO: soil order; LCC: land capability class; EL: elevation; SL: slope; SA: slope aspect; LULC: land use and land cover; DR: distance from road

Max eigenvalue ($\gamma_{max}$) = 7.203730872

$n = 7$

Consistency index (Ci) = ($\gamma_{max} - n$)/(n - 1) = 0.033955145

Random index (RI) = 1.32

Consistency ratio (CR) = Ci/RI = 0.025723595

Results of the weighing of the criteria show that soil class has the highest role in determining land suitability, followed by land capability class, while the slope aspect has the lowest weight. This fact shows that in terms of suitability for agriculture, soil constitutes the most important factor. For this land and soil parameters, soil class has a more important role than land capability class. The soil class represents more major aspects of land including soil fertility, soil physical properties, chemical and biological aspect of soil as well as ease of management in a wider sense. In the case of topographical factors, slope is the most important criterion. For land utilization for agricultural purposes, flat land is more desirable because of the safety factor against erosion. Meanwhile, for the factor of management, land use and land cover constitute more important criteria than distance from road.

Results from the agricultural land suitability map are presented in Figure 3 and Table 4 (columns b and c). It is shown that 87.5% of the land of Bogor Regency is suitable for agriculture, with the large part (43.2%) is moderately suitable (S2).

In terms of land availability, the forest area status map (Ministry of Forestry, 2003) and the OSLUP map (Government of Bogor Regency, 2008) are presented in Figure 4. Based on the FAS map, land can only be used for farming in the area with the status of AOU. Meanwhile, based on the OSLUP of Bogor Regency, land can only be used for agriculture in areas allocated as annual cropping, plantation, dry land and wetlands. Taking into account both maps, a map of suitable land
available for agriculture according to both regulations is presented in Figure 5 (a) and Table 4 (columns d and e). This table shows that the land suitable for agriculture in Bogor Regency amounts to 49.812 ha (16.7%). This consists of various levels of land suitability, most of the land is moderately suitable (S2).

Figure 3. Map of land suitability for agriculture

Figure 4. Map of: (a) Forest area status (Ministry of Forestry, 2003); and (b) allocation in official spatial land use planning (Government of Bogor Regency, 2008)

Figure 5. Map of suitable and available land for agriculture: (a) taking into account FAS and OSLUP, (b) taking into account FAS, OSLUP and actual land utilization

Table 4. Summary of suitable and available land for agriculture in Bogor Regency

| Suitability/Availability | Suitability | Suitable and available, considering FAS & OSLUP | Suitable and available, considering Actual Use |
|--------------------------|-------------|-----------------------------------------------|-----------------------------------------------|
|                          | (a)         | (b)   | (c)   | (d)   | (e)   | (f)   | (g)   |
| Suitability:             |             |       |       |       |       |       |       |
| Highly Suitable (S1)     | 48.762.8    | 16.3  | 14.737.3 | 4.9  | 204.9 | 0.1  |
| Suitable (S2)            | 129.097.7   | 43.2  | 17.554.4 | 5.9  | 5.938.9 | 2.0  |
| Marginally suitable (S3) | 83.623.0    | 28.0  | 17.520.7 | 5.9  | 3.607.6 | 1.2  |
| Not suitable (N)         | 37.354.8    | 12.5  | 37.354.8 | 12.5 | 37.354.8 | 12.5 |
| Availability             |             |       |       |       |       |       |       |
| Not available            | -           | -     | 211.671.2 | 70.8 | 251.732.0 | 84.2 |
| Total                    | 298.838.3   | 100.0 | 298.838.3 | 100.0 | 298.838.3 | 100.0 |
If then the results of this analysis are overlaid with the actual land that has been used for agriculture (for example existing paddy fields, plantations and built area), the land which still allows for the expansion of agriculture is an area of 9,751.4 ha or 3.3% of the area of Bogor Regency (Table 4, columns f and g; Figure 5b). This indicates that the available land for agriculture is not significant, compared with the future requirement for agricultural commodities that will need to increase with population growth. Subsequent analysis can still be done, for example by modelling the needs for land associated with population growth, however it is beyond the scope of this paper.

This analysis shows that there is not much more suitable and available agricultural land in the hinterland of Jakarta. Agricultural land in the hinterlands of other major cities in Java seems to be showing the same phenomena, although not as intense as in Jakarta. The implication is that agricultural areas in the hinterlands of the city will likely not meet the domestic need for agricultural products for much longer. Furthermore, Java itself will be further diminishing its role as the country's major food provider in the future. With the intensive development on Java Island, the pressure on agricultural land will be even greater. For that the solution in the shorter-term is to increase the efficiency use of existing agricultural land on the island of Java, to tightly comply with the official spatial land use plan, and in the long term, to undertake the unavoidable search for alternative land outside Java Island.

CONCLUSIONS and SUGGESTIONS

Land suitability analysis was performed in this research using multi-criteria decision making methods that integrate many land parameters used as criteria. The parameters used include soil order, land capability class, elevation, slope and slope aspect, land use/land cover and distance to road. Results of the analysis indicate that Bogor Regency has 87.5% of suitable area for agriculture at various levels of suitability. Considering the regulation on forest area status and the official spatial land use plan, the suitable and available area of land for agriculture is 16.7%. Of such suitable and available land, much has already been taken for various uses. Considering this actual utilization, the area that can be used as new agricultural land is 9,751.4 ha or 3.3% of the area. The overall analysis shows that not much more land could be used for the expansion of agricultural land to keep pace with population growth. This result implies that in the future, land utilization should be planned more strictly, considering the strict application of existing official spatial land use plan allocation, a more
efficient use of land for agriculture and, for the context of Indonesia, finding agricultural land outside Java Island.

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