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An accurate assessment tool based on intelligent technique for suitability of soybean cropland: case study in Kebumen Regency, Indonesia

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Abstract

In the last few years, the decrease in the land use of soybean affected the reduced of soybean production. Land suitability assessment is an effort to increase the soybean production since the manual method was less accurate. This study aims to apply fuzzy sets and AHP to improve the accuracy of the assessment process of land suitability for soybean crops. The value of five sub-criteria converted into fuzzy sets for standardization process. The weighting by AHP performed to determine the importance level of sub-criteria. Suitability index and final land suitability classes were obtained from the calculation of the fuzzy membership function values and the weights of each sub-criteria before being overlaid with spatial data to produce land suitability map for soybeans. The results of this work showed that 81.42% of the total area was moderate suitability (S2), 11.25% was marginally suitable (S3) and of 7.33% was not suitable (N). From the results of land suitability assessment for soybean crops has been tested and has good correlation with the yield conditions. This study showed that the proposed tool based on Fuzzy sets and AHP were accurate to assess the land suitability of

soybean and can be used as the basis for agricultural planning to optimize the land use and soybean production.

1. Introduction

The rising of the population will increase the demand for food and other agricultural products of more than 3% per year (Baniya, 2008). Increased population was also accompanied by increasing in non-agricultural land use that put pressure on agricultural land resources (Widiatmaka et al., 2016). That is led to an imbalance between the condition of demand for food with the condition of existing farmland. Such as in soy farming. In Indonesia, the land area of soybean crops has been decreasing over the last 20 years ie in 1995 with an area of 1,476,284 hectares of arable land until 2015 at only 614,095 hectares of the arable land area (Global Agricultural Information Network, 2016). From the data of land area in 2015, it only able to produce 963,183 tons of soybeans productions per year (BPS, 2016a,b). The total production was not able to meet requirements the national soybean consumption that reached 2,870,000 tons/year (BPS, 2016a,b). The lack of land use due to a decrease in the land area of soybeans from year to year influence the soybean production. In addition, according to Pilvere et al. (2014) land use that does not suitable will have implications on the low production, which will have an impact on the utilization of land resources is not efficient (Widiatmaka et al., 2016). One effort to increase the agricultural production especially soybean crops is allocated the crops on suitable land (Widiatmaka et al., 2014). Make planning for land area in the form of land suitability assessment is important to allocate soybean cultivation in suitable areas so that it can to optimize the land use resources (Dengiz et al., 2015) and increase soybean production (Zhang et al., 2015; Rathi, R. & Acharjya, D.P., 2018).

Analysis of land suitability assessment can help develop strategies for planning the development of productivity in the agricultural sector (Neupane et al., 2014; Pramanik, 2016). In addition to productivity purposes, land suitability assessment also considers the element of protection (FAO, 1993; Wali et al., 2016). Protection means to conserve natural resources from the damage such as prevent soil degradation or erosion due to land management processes continuously (FAO, 1976; Elaalem et al., 2011). Soil should be used in accordance with their capacity to meet human needs to ensure the sustainability of the ecosystem (Gamew, 2012).

In the land suitability assessment process, many factors must be considered (Akinci et al., 2013; Khoi and Murayama, 2010). In addition, there is no specific standard about the number of criteria that must be considered when assessing the potential of land suitability (Akinci et al., 2013). That is because each of the criteria that affect

of land suitability has a level varying interests (Zhang et al., 2015; Elsheikh et al., 2013). To determine the importance level of each criterion can be done by weighting such as research (Gamew, 2012; Tsiko and Haile, 2011). With the weighting for each criterion can reflect the relative importance and have a better impact on the result later (Tsiko and Haile, 2011). There are many methods of weighting that can be used to determine importance level of criterion. One method that is often used to assess land suitability is AHP (Analytical Hierarchy Process).

The use of conventional methods are based on manual procedures in the process of crop selection and prediction that is a hard method and also it has a weakness because it takes a long time and large funds (Kamkar et al., 2014). The use of AHP method in the assessing land suitability can replace conventional methods in order to determine and reduce the weight-related criteria influential and combined with the map layers suitability as a linear additional relation to the processing of raster data in mapping land suitability using GIS (Geographic Information System) (Deng et al., 2014; Ayehu and Besufekad, 2015). In addition, the weighting using AHP through pairwise comparison is much better than direct assignment of weight because it has advantages for checking the consistency of the weight by calculating the ratio of consistency (Tsiko and Haile, 2011). AHP method used in the decision-making process assuming that the ratio of the two elements from several criteria, real-time importance (Neupane et al., 2014).

In addition to a scoring, in land suitability assessment process is also necessary to standardize of each criterion used. The purpose of standardizing is to classify the relative importance of each criterion into suitability classes (Baniya, 2008). The value of weights and standards used to derive land suitability index (Zhang et al., 2015; Deng et al., 2014). The process of standardization of criteria for the land suitability assessment usually is done by manual method that is based only on the opinions or knowledge of some experts, farmers and several reviews of the literature through the determination using the specified scale (Baniya, 2008; Dengiz et al., 2015). It is considered less than optimal to determine the value of standardized criteria, because of disuse of an exact calculation of a specific algorithm. Choosing the most appropriate algorithm for assessing land suitability is important for land use planning that will be carried (Zhang et al., 2015). Fuzzy sets used in process of standardizing the criteria because of it has potential to provide better evaluation than using a discrete approach as it introduces subjectivity and ambiguity in the analysis (Papadopoulos et al., 2015). Fuzzy sets method had been selected because it has an excellent mechanism to change the numerical data of various magnitudes (Zhang et al., 2015; Anitha, A. and Acharjya, D.P., 2017). By using fuzzy in the standardization process, the range of values of land suitability classes will be equal for each criterion at range 0–1 (Suh and Brownson, 2016).

Implementation of Fuzzy sets and AHP has been widely used in several studies of decision making. In the study by Tsiko and Haile (2011), the best choice for the construction of water reservoirs indicate that the implementation of Fuzzy and AHP provide better mechanisms and transparent for the results compared with the conventional method. The study from Mokarram and Najafi-Ghiri (2016) show that the implementation of Fuzzy and AHP has high accuracy for evaluating the percentage of potassium saturation percentage (KSP) in the study area. The study by Ezzabadi et al. (2015), application of Fuzzy and AHP method can efficiently improve the performance of the European Foundation for Quality Management (EFQM) model-based power plant in Iran. The study by Li et al. (2014) on evaluation of the efficiency of transit vehicle shows that the resulting model is more applicable and has good efficiency. Research by Elaalem et al. (2011) shows that Fuzzy AHP approach for modeling land suitability evaluation is better than Ideal Point approach because of the Ideal Point approach has some bias, while specifically for the implementation of Fuzzy and AHP on the land suitability assessment in some studies of Zhang et al. (2015), Wali et al. (2016), Deng et al. (2014) showed that Fuzzy and AHP are a powerful combination, effective and has a very good mechanism in the process of assessment of land suitability. From these studies, proved that implementation of combination methods of Fuzzy and AHP effective to be an alternative in the decision-making process.

Based on the data from the soybean land area (BPS, 2016a,b), there is a decrease in the soybean land area during the period of the last few years. Less optimal of soybean land use due to a decrease in land area and influential at the decline of soybean production (Global Agricultural Information Network, 2016). It required an effort to increase the land use through land suitability assessment. The objective of this study is to optimizing of the land use and soybean production's through land suitability assessment using Fuzzy and AHP. Fuzzy sets and AHP methods applied to be able to replace the manual scoring method which is still applied in some studies. In this study, Fuzzy sets used to calculate the value of standardization of criteria while AHP method will be applied to the process of weighting the criteria. The results of the calculation of the value of standardization using Fuzzy and weighting criteria using AHP is used to calculate the suitability index and then used to the overlay process of making land suitability map for the soybean crop.

2. Study area

Kebumen is one of the regencies in the southern part of Central Java province (Fig. 1) which covered an area of 132,872.9 km^2, with the condition of some areas are coastal areas, hills, and most of the lowland, with a height region range of 0−710 masl. The climatic conditions in Kebumen regency has recorded an average monthly rainfall of 239 mm from an interval 2010−2014. Kebumen regency is dominated by
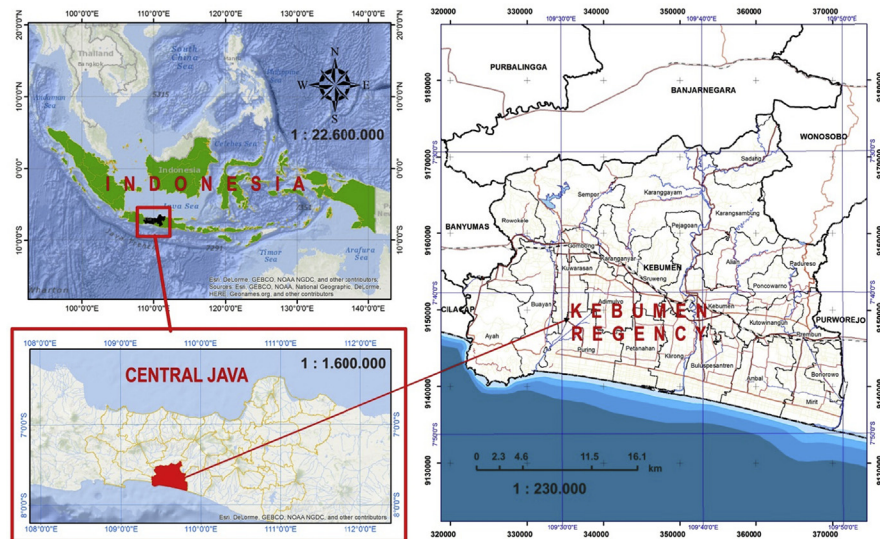
Fig. 1. Location of the study area includes elevation and slope conditions of an area.

flat land with a slope of only 0−1% level lowland areas and is also dominated by land with a slope of 15−35% in the hilly which covers a land area of up to 34.9% of the land area is suitable for growing types food crops and plantations crops.

Most regions in Kebumen Regency, dominated by alluvial plain landform with clay sediment material that reaches an area of about 45,877.02 ha, or approximately 34.5% of the total area. Such conditions are very suitable for agriculture. The next landform is dominated by hills tectonic material of calcareous clay and sandstone rocks covering an area of 29,105.00 ha (21.9%), and the old hills volkan with andesite material and basalt area of 10,252.06 ha (7.7%).

In 2013, area of Kebumen recorded as 132,872.9 km^2, which 31.03% is a wetland and 68.97% is dry land. The use of dry land (not the fields) is divided into agricultural land amounting 48.44% and not for agriculture amounting to 51.56%.

Besides being a producer of rice, Kebumen regency is also a producer of various other food crops such as maize, cassava, sweet potato, peanut, soybean and mung bean. Based on data obtained from the Central Statistics Agency of Kebumen regency in 2014, all food crop commodity production has decreased. Commodity product for corn is 0.31%, 3.27% for cassava, 19.43% for sweet potato, 23.73% for peanuts, 49.72% for soybeans and 25.15% for mung beans. Soybean production is the sector that experienced the largest decline of nearly 50% of production in 2013. In fact, Kebumen regency is the fifth largest soybean production area in the Central Java province. The action to increase production is necessary since Indonesia has not been able to fulfil demand consumption which reach 2.87 million tons/year. That is make Indonesia must import soybean from other countries.

2.1. Data set

In this study, we use spatial data to assess of land suitability for soybean crops that has been generated and possibly use by the relevant agencies. The spatial data consists of map data of rainfall, elevation, slope, soil type and soil texture. This research conducted for the assessment of certain types of agricultural crops, the use of the parameters of rainfall, temperature, pH, salinity and levels of organic matter is required (Akinci et al., 2013). For the temperature data, it is represented by the data of rainfall and elevation, while the data of organic substances, pH and salinity are already represented by the data of soil type. In addition, to separate the map data of each sub-criterion, we also use the data of land suitability maps of soybean crop that we get from DPU (Dinas Pekerjaan Umum) Central Java, Indonesia and BPTP (Balai Pengkajian Teknologi Pertanian) Central Java, Indonesia. DPU is a government agency in the province that has the a task in the planning and implementing regional development. Meanwhile, BPTP is a government agency that is under research and development institute assigned to conduct the assessment of agricultural technologies. That's data used to validation as a correlation with previous studies that have been validated before.

2.2. Data processing

The spatial data from DPU processes by using ArcGIS 10.1. The processing of spatial data is done by overlaying the 5th of spatial data using intersect techniques to produce a map data of land units. From the intersection process was obtained 80 of land unit. Each of land units has a different characteristics. The Data of land units extract into data excel for determined the standardization value of each sub-criterion.

3. Method

In outline, the processes and stages of this research to assess of land suitability for soybean crops using Fuzzy and AHP method can be presented in the form of flow-chart at Fig. 2.

3.1. Identification of criteria influencing the land's suitability

In land suitability, there are 3 main factors that can affect the land suitability of an area. They are physical factor, social factor and economic factor (FAO, 1976; Deng et al., 2014). Physical factors is the most influential factor on the land suitability (Baniya, 2008; Wali et al., 2016). In addition, economic and social factor tend to be unstable because it is easily controlled by human (Zhang et al., 2015). Therefore, on the land suitability assessment for soybean crop is only based on
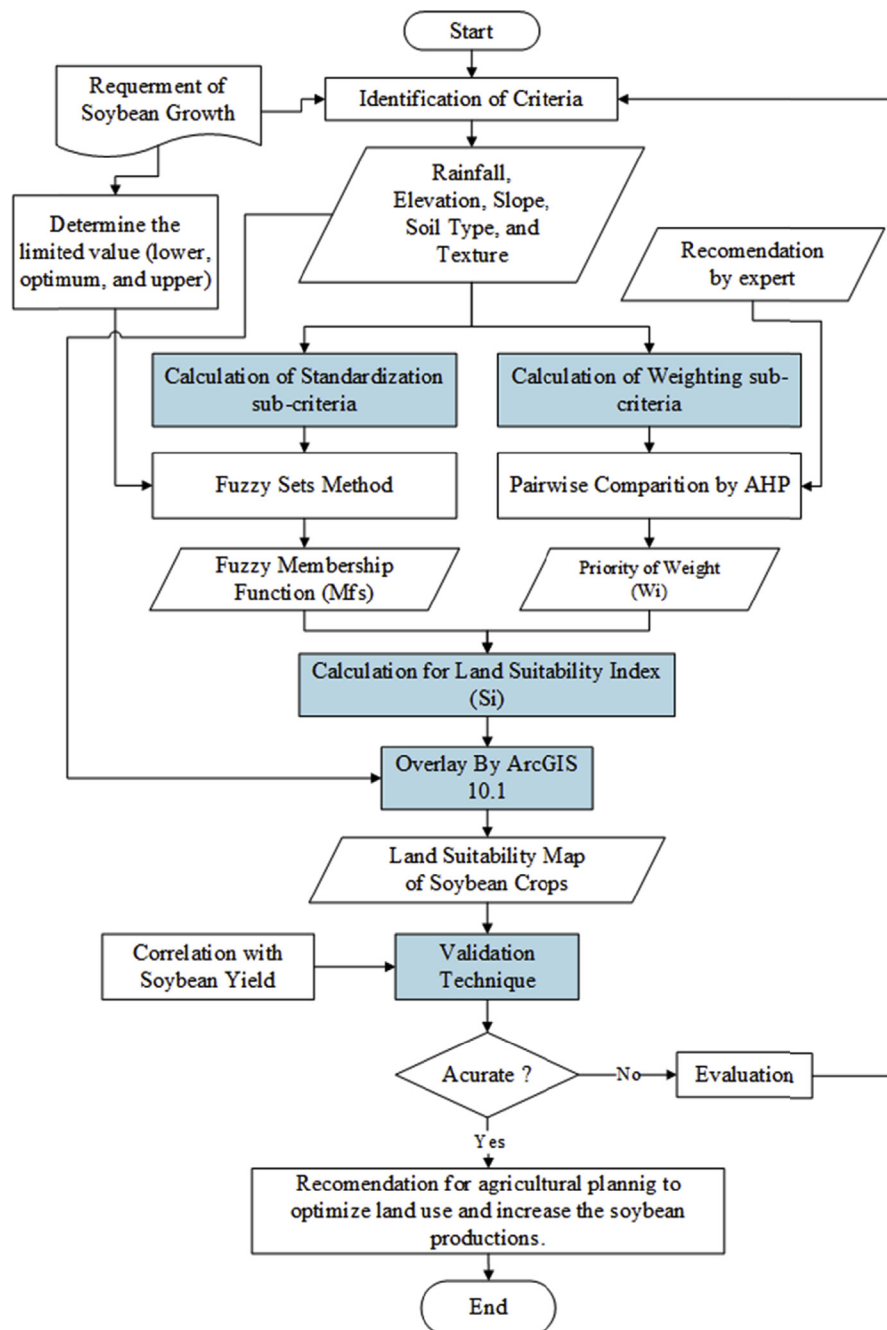
Fig. 2. Framework for assessment of land suitability for Soybean Crops using Fuzzy sets and AHP Technique.

the physical factor. The selection and determination of the appropriate criteria are essential to develop land suitability assessment (Deng et al., 2014). Many physical factors that can be used as a reference for assessing the suitability of soybean field such as in Rota et al. (2006), Meena et al. (2014), and Sudaryono and Wijanarko (2011) but it is impossible to cover all of these criteria (Zhang et al., 2015). Based on some literature review from the study Widiatmaka et al. (2014), Zhang et al.

(2015), Akinci et al. (2013), Elsheikh et al. (2013), Deng et al. (2014), Linda et al. (2015), Rathi, R. & Acharjya, D.P. (2018) have been selected three main criteria that consist of 5 sub-criteria, there are climate (rainfall), topography (elevation and slope) and soil physics (soil type and soil texture). The main criteria such as soil organic content data are not included because it was represented by soil type.

According to De la Casa, and G.G. Ovando (2014) climatic conditions give affect to the potential of agriculture and crop production characteristics in a region. For the criteria of the climatic conditions, we identified that the growth and development of soybean crops are influenced by the availability of water. The amount of available water for crops is highly depend on the rainy season, and the distribution of rainfall (Kazemi et al., 2016). The limited amount of water resulted in a gap in the production of soybean (Sentelhas et al., 2015). The optimum of average rainfall to fulfil the growing of soybean crops ranged in 500-3,500 mm during the growth period of soybean (Sudaryono and Wijanarko, 2011). Generally, climatic condition affect the characteristics and potential of agricultural production in a region. For the criteria of topography include elevation and slope condition of an area. Elevation will affect the temperature change that exist in a region (Akinci et al., 2013). The higher elevation of an area lowered the temperature in the area. Soybean plant generally grow well in area with an elevation around <300 masl (Kamkar et al., 2014). In addition, the soybean crop will grow well on the area that has a slope of 0−30%, but for the most optimum slope ranged 0−8% (Rota et al., 2006). The slope is very influential on the land suitability condition because of effects on the vulnerability of soil erosion, irrigation systems, land management and land drainage processing, so it has the role for the quality of future plant production (Akinci et al., 2013). Additionally, the slope also indirectly limits the productivity of the plant because it will affect the nature of the soil properties (Kazemi et al., 2016). For the physical properties of soil condition include soil type and texture. The soil is the main medium for plants to grow and develop (Ayehu and Besufekad, 2015). Soil contains various elements that support plant to grow such as nutrient content (Ayehu and Besufekad, 2015). The different types of soil give affect to root growth and distribution of the amount of available water (Dugas et al., 1990). Based on the level of soil fertility, the soil type of alluvial is more suitable for growing crops. Alluvial soil type has tended argillaceous soil texture and clay that are smooth so suitable for root soybean crops. In sandy soil types that is rough, soybean crops will be difficult to grow. This is related to the availability of water to support growth and to grow other environmental factors.

3.2. Standardization of sub-criteria by fuzzy membership function

The each of sub-criterion has different ranges value. The standardization of sub-criteria is performed to equalize the value of each sub-criterion into the same

interested value (Suh and Brownson, 2016). In order to equalize the value of the interest of the sub-criteria into comparable value, it is necessary to standardize each of sub-criterion into the same unit of measurement (0−1) (Papadopoulos et al., 2015; Suh and Brownson, 2016). Fuzzy method is used in the standardization process because it has an excellent mechanism for changing the numerical data of various magnitudes in the value of membership function to be used as a representative of land suitability classes (Zhang et al., 2015; Anitha, A. and Acharjya, D.P., 2017). The fuzzy sets method is a mathematical calculation method that was first created by Zadeh in 1965. It is used to measure the degree of uncertainty and imprecision in the data non-discrete (Singha and Swain, 2016). The use of fuzzy sets method in the decision-making process can reduce the inability of AHP in dealing with the uncertainty level of importance of land suitability sub-criteria.

The degree of fuzzy membership function is used to determine the value of the standardization sub-criteria (Khoi and Murayama, 2010). By integrating Fuzzy Membership Function (FMFs), the value of sub-criteria will be converted into the range of 0−1, so that all values of each sub-criterion has the same range of value. In this work, we used two curves models of fuzzy membership function. They are Linear-parabolic curve model and Linear-sigmoid curve model. We use the optimal requirements of soybeans growth to construct these models (Table 1).

Parabolic curve is used for sub-criteria which have a lower limit, lower optimal limit, optimal upper limit, and the upper limit (Zhang et al., 2015). Parabolic curve shape of the model (Fig. 3) (Eq. (1)) used was a trapezoidal shape model because that is linear and firm.

$$
MFs(xi) = \begin{cases}
0; & x \leq a \ or \ x \geq d \\
\dfrac{x-a}{b-a}; & a < x \leq b \\
1; & b < x \leq c \\
\dfrac{d-x}{d-c}; & c < x < d
\end{cases}
\tag{1}
$$

Table 1. Suitability assessment sub-criteria, membership function model, and threshold values.

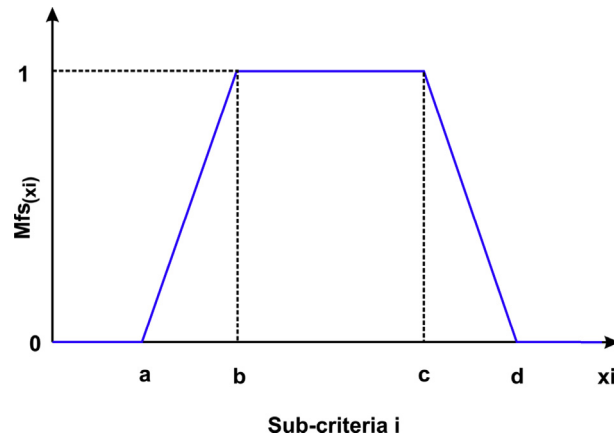| Criteria	Sub-criteria	Fuzzy function				Membership function model
		Lower limited	Optimum lower limited	Optimum upper limited	Upper limited (γ)	
Climate	Rainfall (mm)	500	1000	1500	3500	Parabolic
Topography	Elevation (m)	0	-	-	600	S-down
	Slope (%)	0	-	-	30	S-down
Soil physics	Soil type	0	-	-	10	S-up
	Texture	0	-	-	10	S-down

Fig. 3. Linear-parabolic curve model.

where, $MFs_{(xi)}$ is the degree of membership value, a is the lower limit value, b and c are the optimum value range, d is the upper limit value so that $a < b < c < d$, and x is the real value of the sub-criteria.

For sigmoid curve model divided into two models that are Linear S-up curve model and Linear S-down curve model. Linear S-up curve model (Fig. 4) (Eq. (2)) is used when the suitability increases with increasing value of sub-criteria.

$$MFs(xi) = \begin{cases} 0; & x \le a \\ \dfrac{x-a}{b-a}; & a < x < b \\ 1; & x \ge b \end{cases} \tag{2}$$

where a is the lower limit value, b is the upper limited value, and x is the original value of sub-criteria.
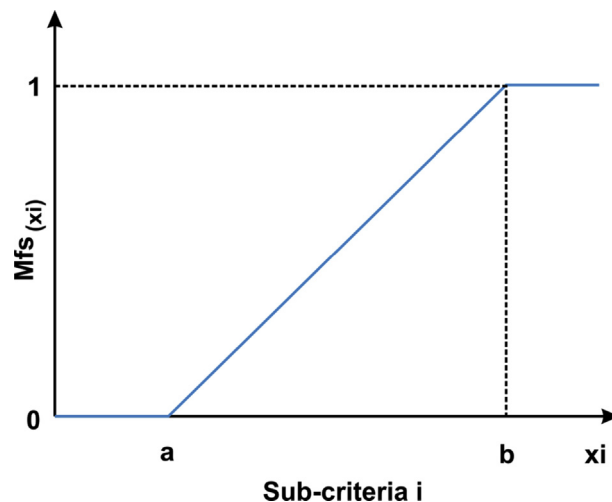

Fig. 4. Linear S-up curve model.

While Linear S-down curve model ([Fig. 5](#)) ([Eq. (3)](#)) is used when the suitability decreases with increasing value of sub-criterion.

$$MFs(xi) = \begin{cases} 1; & x \leq a \\ \dfrac{b-x}{b-a}; & a < x < b \\ 0; & x \geq b \end{cases} \tag{3}$$

For the determination of input value in fuzzy sets is based on the minimum and maximum value of requirements grow plant (Elsheikh et al., 2013; Kamkar et al., 2014; Deng et al., 2014). Determination of the classes of suitability requirements soybean growth is based on some literature. The used of fuzzy membership function curve model is different in each of sub-criterion. This difference is based on the sub-criteria suitability to the terms of soybean growth ([Table 1](#)). Based on [Table 1](#), soybean plant can grow well in rainfall conditions: 500 mm−3500 mm, where 1000 mm−1500 mm is the optimal rainfall condition for soybean growth. If lower than 500 mm or higher than 3500 mm is not suitable for soybean growth. The relationship between the values of those factors and soybean growth suitability can be best described by using linear-parabolic curve ([Fig. 3](#)), which have a lower limit (a), optimal lower limit (b), optimal upper limit (c), and upper limit (d). Linear-sigmoid curve was used as membership function for Day 20 and Mo.

Linear S-down curve was used as membership function for elevation and slope. Increasing the value of elevation area will decrease the suitability value of soybean growth. In [Table 1](#), soybean plant can grow well under elevation condition: 0−600 masl. If the elevation condition is too high it is not suitable for soybean growth because it has a low temperature. For slope condition, soybean crop suitable to be
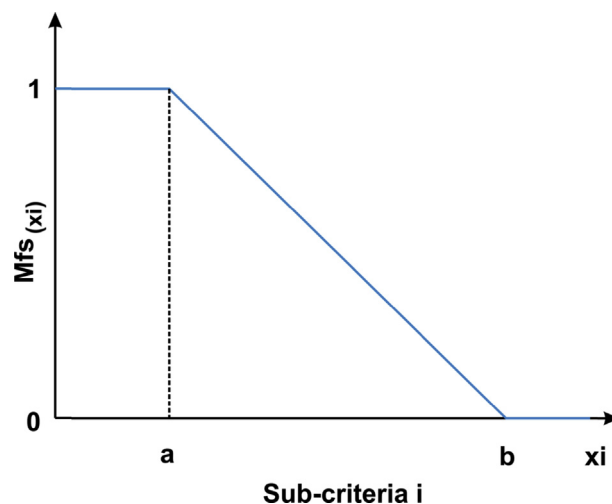

Fig. 5. Linear S-down curve model.

planted on sloping land and less suitable to be planted on steep land. So, to standardize the process of elevation and slope, Linear S-down curve model is used.

For qualitative data such as soil type and soil texture, can not be directly inserted into the calculation of fuzzy membership function. Therefore, we classify into the range of 0−10 and then we insert into the calculation of fuzzy membership functions where a range of 0−10 have represented value of each type of soil that is alluvial, glei-humus, latosol, regosol, lithosol, podsolic, mediteran and renzina. The range value of 0−10 is divided into four classes of suitability based on the FAO guidelines in 1976. The results of the calculation of fuzzy membership function determined the average value for each class suitability. So as to produce value for each condition of soil type that highly suitable with the value of 0.875 (alluvial and glei humus), moderate suitable with the value of 0.608 (latosol), marginally suitable with the value of 0.358 (rhogosol), and not suitable with the value of 0.1225 (lhitosol, podsolic, mediterranean, and renzina).

The classification of soil type into suitability classes is based on the soil fertility and organic matter content is owned by each type of soil. For the soil texture we also classified into four classes of with details highly suitable with the value of 0.86 (CL, SCL, L, SiL), moderate suitable with the value of 0.608 (SL, C, SiC, SiCL), marginally suitable with the value of 0.358 (SS, LS), and not suitable with the value of 0.108 (S). The classification of soil texture is based on the level of smoothness and roughness of each soil texture and is based on (Meena et al., 2014).

3.3. Determination of weights by AHP

Each of sub-criteria has importance level that differently in affect the land suitability for crops (Zhang et al., 2015). The Weighting in land suitability is useful to know the importance level of each sub-criterion of the land suitability (Deng et al., 2014). In this study, AHP method is selected and used for weighting the criteria and sub-criteria to the land suitability assessment for soybean crops. AHP is one of the multi-criteria approaches that is the most widely known and commonly used in the analysis of agricultural land use suitability (Akinci et al., 2013). AHP method has been selected, because it is one of the best approaches to handle some of the factors that are heterogeneous, which is based on a hierarchical structure represent the interests and relationship factors in situations of the multi-criteria decision (Zhang et al., 2015). In addition, AHP weighting assigned to replace the weighting process using conventional methods, where the weighting is done directly based on expert opinion. Assign weights using AHP through pairwise comparison is more suitable than the direct assignment of weights because of its advantages in checking the consistency of the weight by calculating the ratio of consistency (Tsiko and Haile, 2011). By integrating the AHP, it can help decision makers to find out the best fit for purpose and their understanding of the problems with some contradictory and subjective criteria (Ezzabadi et al., 2015).

The first step to calculate the weighting of the sub-criteria using AHP is developing the model hierarchy of the study (Zhang et al., 2015) (Fig. 6) which consists of four levels, there are objectives, criteria, sub-criteria, and output.

The second step is to determine the pairwise comparisons. In the process of pairwise comparisons, the each sub-criterion is compared each other using a comparative scale 1−9 to determine the relative importance of each sub-criteria (Khoi and Murayama, 2010). This process was assisted by eight experts from BPTP Central Java who experienced in the crop and soil. Determining the value of pairwise comparisons by experts that is integrated by AHP will most likely produce a more accurate evaluation (Linda et al., 2015). The results of pairwise comparisons from eight experts are different. To combine the experts opinion is using geometric mean method (Mosadeghi et al., 2015) shown in Table 2. The geometric mean is used because it has the consistency of average results that is better than the average method is often used (Yucheng et al., 2007). To calculate geometric mean is used the (Eq. (4)). The process of calculating the geometric mean is done for each value pairwise comparison and for that results of calculations are shown in Table 2.

$$G = \left(\prod_{i-1}^{n} xi \right)^{1/2} \tag{4}$$

where: G: Geometric Mean

x_i: The value of each pairwise comparison

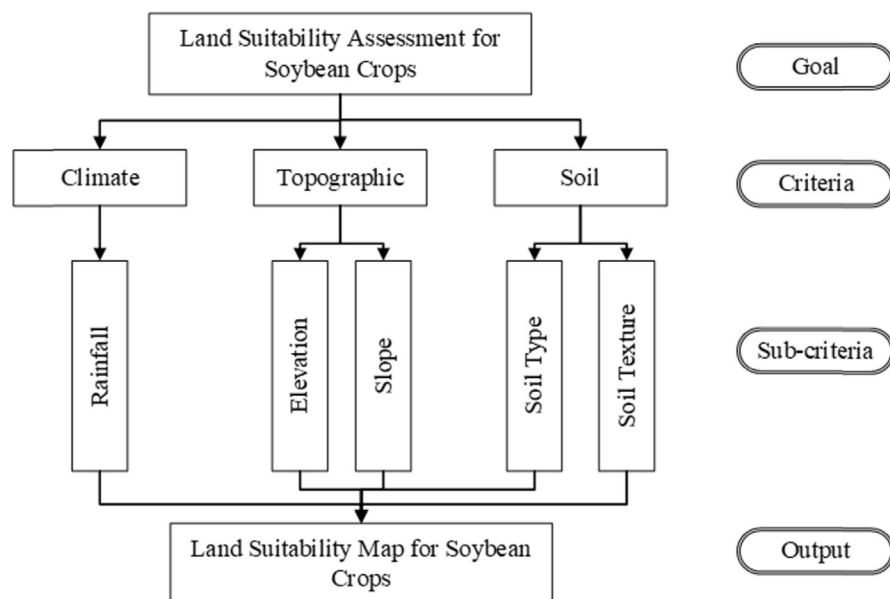n: number of criteria or sub-criteria

Fig. 6. Hierarchy model of the study by AHP.

Table 2. Calculation of pairwise comparison matrix with geometric mean from 5 experts.

Sub-criteria	Rainfall	Elevation	Slope	Soil type	Texture	Weights
Rainfall	1	1,805	1,009	0,552	1	0,197
Elevation	0,554	1	0,631	0,584	0,972	0,145
Slope	0,991	1,303	1	0,588	0,684	0,171
Soil type	1,810	1,713	1,701	1	1,097	0,277
Texture	1	1,028	1,462	0,911	1	0,210

Max. eigenvalue (λmax) = 5,043.
$n = 5$.
Consistency index (CI) = 0,011.
Ratio index (RI) = 1,12.
Consistency Ratio (CR) = 0,001.

The next step is to calculate the weight of a priority. The results of calculation on the pairwise comparison were calculated by finding out the total value and average in each cell of the table. The results from the average called to the weight of priority, shown in Table 2. The final step is to calculate the consistency ratio (CR) of the weighting (Eq. (5)). To calculate the CR is required consistency index (CI) and ratio index (RI). CI obtained from the calculation max eigenvector (λmax). As for RI based on the table ratio index show in Table 3.

$$CR = \frac{CI}{RI} \tag{5}$$

If the value of CR $\leq$ 0.1, it means that the priority weight obtained a good level of consistency and can proceed to the next steps of assessing the land suitability. If CR > 0.1 occurred it means there is inconsistencies on priority weights. It should be evaluated, starting from determining weight stage. It must be done for weighting by experts (Baniya, 2008).

The calculation result of CR is equal at 0.01, it shows that the weighting by eight experts have a very good level of consistency because the CR value is below of 0.1. This shows that the weighting performed can be accepted and can be used for the next process of land suitability assessment for soybean crops.

3.4. Calculation of land suitability index (*Si*)

After the value of standardization with fuzzy ($Mfs_{(xi)}$) is obtained and the weight of each sub-criterion (*Wi*) of the results of calculations using AHP is obtained, the next

Table 3. Ratio index (RI).

n	1	2	3	4	5	6	7	8	9	10
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

step is to determine the land suitability index of soybean crops (Khoi and Murayama, 2010). The process of determining land suitability index is applied for suitability of each sub-criteria. Land suitability index (Si) is a process to classify the criteria or sub-criteria into land suitability classes that will be used to overlay the making of land suitability map (Motuma et al., 2016). Classifying class suitability of each sub-criterion is based on the FAO guidelines (1976). They are divided into four suitability classes, there are highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N). Determining the range value of each class of land suitability index is shown in Table 4.

The calculation process of land suitability index (Si) (Eq. (6)) (Elaalem et al., 2011; Deng et al., 2014; Zhang et al., 2015) is sum the value multiplication result of the standardization of each sub-criterion ($Mfs_{(xi)}$) with the weight of each sub-criterion (Wi).

$$S_i = \sum_{i=1}^{n} Mfs_{(xi)} W_i \tag{6}$$

Where, Si is the value of the land suitability index, $Mfs_{(xi)}$ is the standardization value of sub-criteria xi, and Wi is the weight values of sub-criteria xi. From the calculation of land suitability index from each sub-criterion then will overlay to the map of each land suitability sub-criteria.

3.5. Overlayed the spatial data and suitability index by GIS

The use of spatial data will more easier to the process of land suitability maps instead of using regular data because it presents a very accurate information about the geographical conditions of the region more widely. Spatial data from several sub-criteria is used to create the land suitability maps through one of the overlay technique that is intersection. Map overlay process performed using software by Esri that is ArcGIS 10.1. The overlayed results from 5 spatial data is in the form of 80 unit of land which is exported into excel format data as a GIS database. The next step is to determine the value of standardization sub-criteria and weighting of each data. From the calculation of the standardization value and weight, it will produce the value of suitability index for further classified into four classes into four

Table 4. The range values of land suitability index classes.

Intensity of limitation	Suitability class	Land index
Highly suitable	S1	0,8−1
Moderately suitable	S2	0,5−0,8
Marginally suitable	S3	0,25−0,5
Not suitable	N	0−0,25

suitability classes based on FAO guidelines 1976. That are S1, it represented the high suitable land unit for growing soybean crops without restriction; S2 represented the moderate suitable land units with some limitations; S3 represented the marginally suitable land unit with many limitations; and N represented the unsuitable land units for growing soybean plant (Zhang et al., 2015). The classification of suitability classes is based on the value of suitability index that have been obtained for each sub-criteria before. The next process is inserting the Excel data into ArcGIS 10.1 software. The process continued with overlay GIS database of each spatial data with the value of suitability index and then land suitability maps for soybean crops had been obtained and shown in Fig. 12.

4. Result and discussion

4.1. Suitability of each sub-criterions

In Figs. 7, 8, 9, 10 and 11 show the distribution for suitability level of 5 sub-criteria that are distribution of rainfall suitability classes (Fig. 7), elevation (Fig. 8), slope (Fig. 9), soil type (Fig. 10), and soil texture (Fig. 11) in Kebumen Regency area.

4.1.1. Climatic suitability

For rainfall conditions (Fig. 7) shows the rainfall condition was quite high. Ranging from 2750-3500 mm rainfall conditions is less suitable for soybeans growth. Meanwhile, only a quarter-three regions that have a moderate suitability with moderate rainfall is 2250−2750 mm and the rest is a region that not suitable, which includes a small part of the north with condition 3500−3750 mm.
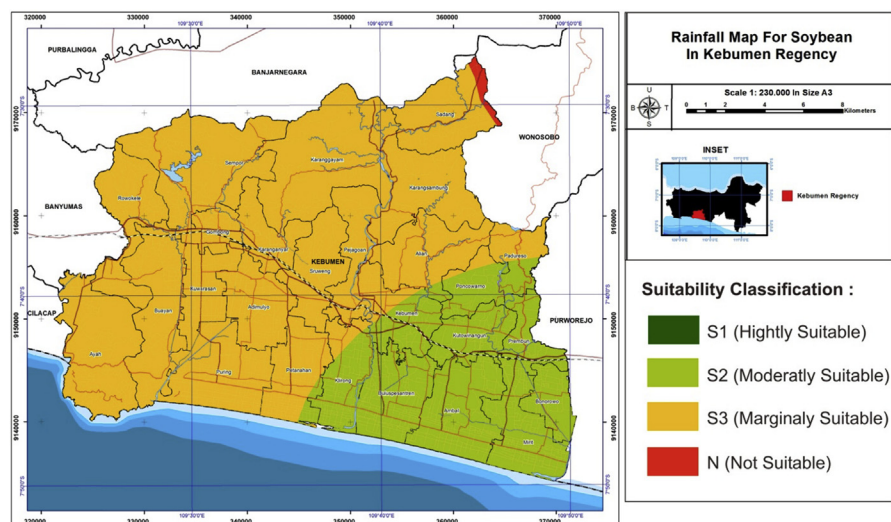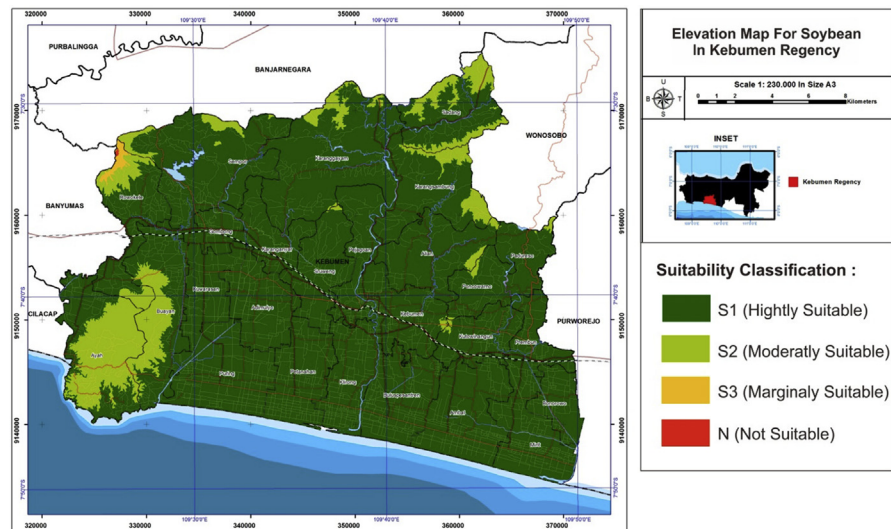

Fig. 7. Suitability map of rainfall.
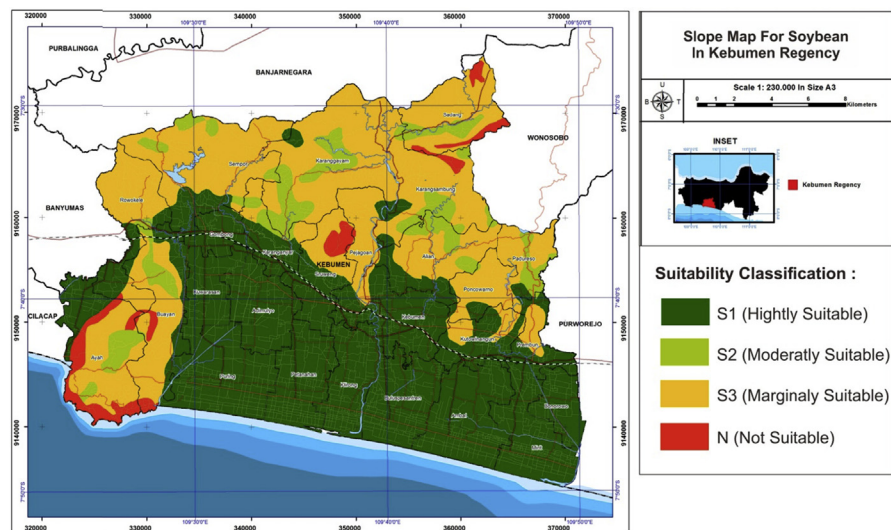
Fig. 8. Suitability map of elevation.

Fig. 9. Suitability map of slope.

4.1.2. Topographic suitability

For elevation condition (Fig. 8) showed that about 80% of Kebumen Regency have a high suitability classification with the type of contour elevation is coastal lowland (0−300 masl). While about 15% of the area have an undulating hilly (300−500 masl) with moderate suitability classification and the remaining about 5% or less is a mountainous area (>500 masl) which is a region with a low marginal suitability classification. Meanwhile, the slope condition in Kebumen Regency (Fig. 9) identified that about >50% is a land with a slope of 0−8% is very suitable for soybeans growth. While the rest of the area is located on the hill and mountain that have a
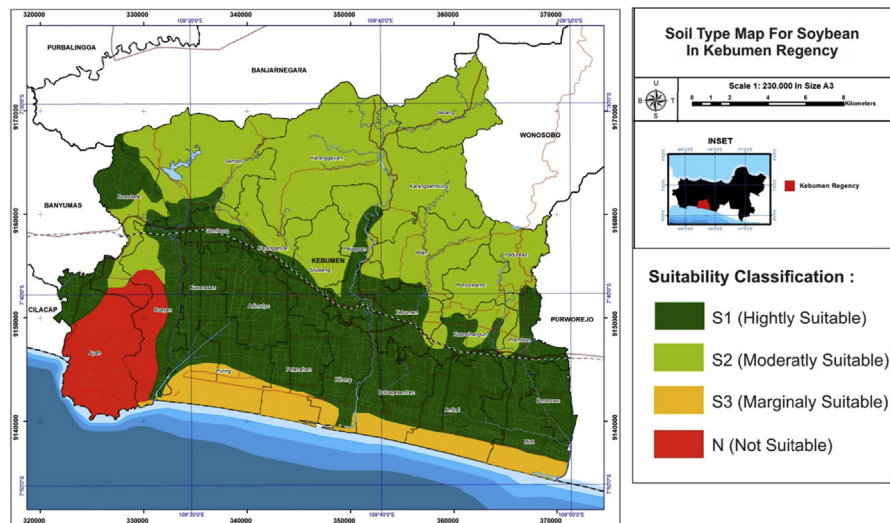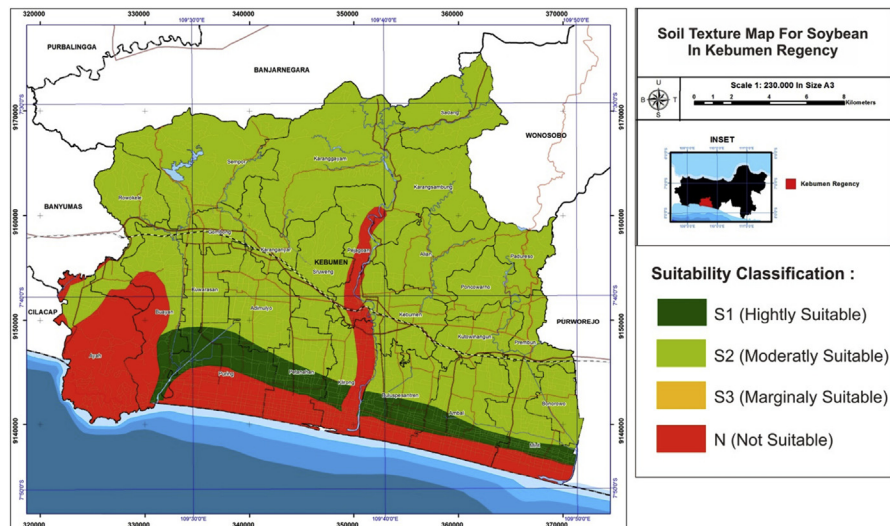
Fig. 10. Suitability map of soil type.

Fig. 11. Suitability map of soil texture.

slope of more than 15% which is an area that was less suitable until not suitable for soybean crops with only a few where have the slope of 8−15% is an area with a moderate level.

4.1.3. Soil suitability

For soil condition includes of soil type and soil texture. We identified that for the condition of soil types distribution (Fig. 10) in Kebumen Regency is dominated by the distribution of alluvial soils in south which is a type of soil very suitable for soybean crops. Glei humus is also suitable for the soybean crop because it

contains a lot of nutrients required for soybeans. Glei humus is often found in low-land areas in the central part of Kebumen Regency that stretches from east to west area. In the highland in the northern part is dominated by soil type of latosol. Latosol is a soil that is often found in the highlands area and these is moderately suitable for food crops such as soybean crop. In coastal area or close to the sea is found regosol soil types that tend to be rough because that is young of alluvial soil. So it is less suitable for soybean crop. Meanwhile, only a small fraction of soil lithosol, mediterranean and renzina located in the southwestern region which is a region with the dominance of limestone mountain so it is not suitable for the soybean crop. For the soil texture (Fig. 11), there are 3 distribution of soil texture that is dominated in Kebumen regency. They are clay-texture (C) soil having clay character and quite suitable for soybean crop. It is mostly spread in Kebumen. In addition, there are a loam-textured (L) soil having smooth character. So it is suitable for soybean crop. The last is sand-textured (S) soil that tend to be rough and not suitable for soybean crop. It spread in coastal area and watersheds.

4.2. Land suitability of soybean in Kebumen Regency

By integrating spatial data of 5 sub-criteria that has been standardized (Table 1) and have the weight of each (Table 2), land suitability map for soybean crops in Kebumen Regency has been successfully created and presented in Fig. 12 through the overlay process by using GIS. Distribution broad of each land suitability classes for soybean crops is presented in Table 5.

In terms of physical condition, most of the land in Kebumen Regency is moderately suitable for soybean farming and only in the southwestern region that are more likely
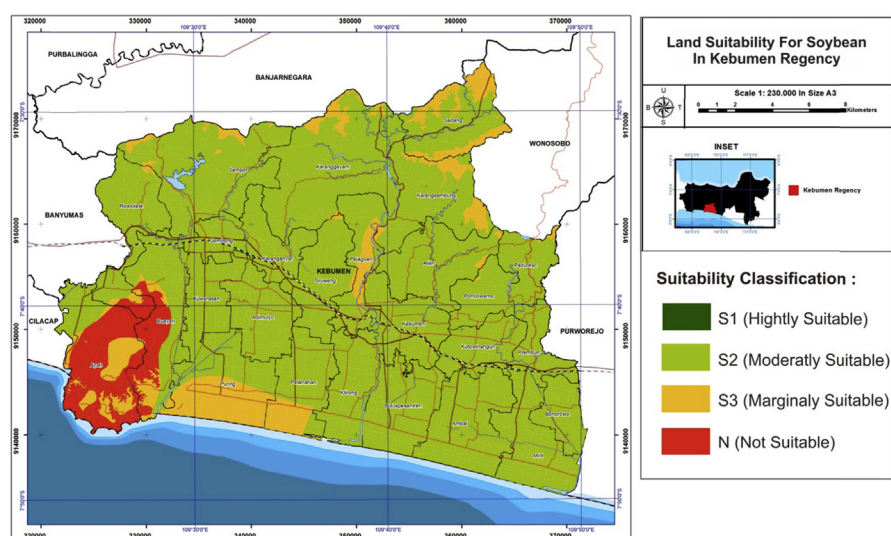

Fig. 12. Land suitability map for soybean in Kebumen Regency.

Table 5. Distribution of total area of soybean land suitability in Kebumen regency.

Suitability classification	Index suitability score	Area (ha)	% of total area
Hight suitability (S1)	0,8−1	0	0
Moderate suitability (S2)	0,5−0,8	108182,25	81,42
Marginal suitability (S3)	0,25−0,5	14948,63	11,25
Not suitability (N)	0−0,25	9742,01	7,33

not suitable. In the southwestern region is the region with the dominance of large limestone mountains. Land in the southwestern region tend to be arid because the majority of soil types dominated lhitosol, mediterranean and renzina are not suitable for agriculture. In addition, the contour of the land is undulating with steep slope condition. Based on the Table 2, it showed that the soil condition has the greatest influence for land suitability among other criteria. According to the soil condition do not suitable, it makes the land is not good for soybean even the climate and topography is quite suitable. Based on the distribution table area of the land suitability for soybean crop (Table 5), showed that most of the area has a concordance rate of moderate suitable (S2) amounted to 81.42% of the total land area, while only 11.25% less suitable (S3) and amount to 7.33% is not suitable (N) for the soybean crop.

4.3. Discussion

In this study, land suitability assessment for soybean crop in Kebumen Regency, Indonesia successfully created in the form of mapping by integrating GIS technology, fuzzy sets method and AHP method. Five sub-criteria: rainfall, elevation, slope, soil type and texture have been selected for standardization value that is calculated using fuzzy membership functions (FMfs). Each of the five sub-criteria has a different ranges values and also have different magnitudes units. Such as rainfall has a range values of 500−3500 in mm, and elevation has a range value of 0−600 in meters, and slope has a range values of 0−100 in % as a unit. By integrating fuzzy sets, each of the value of the different sub-criteria can be classified into the same value in range of 0−1. In addition, the extraction of sub-criteria value into fuzzy membership function (FMfs) has a primary objective to facilitate the standardization process (scoring) of sub-criteria. The process of standardization sub-criteria is used to classify the value of sub-criteria into land suitability classes that is useful for calculating the suitability index values later. It would be more effective than the standardization process using conventional method by manual scoring like in the study (Baniya, 2008; Wali et al., 2016; Akinci et al., 2013). In the manual scoring process (conventional), the determination of scoring or standardized value is based only on the opinion of several experts without through the calculation process using a specific algorithm. That would lead the scoring is subjective. Use of

fuzzy sets method in determining the value of standardization will reduce the subjectivity which tends ambiguous because of the ability of fuzzy method is to handle vagueness or ambiguity of a problem.

Additionally, in determining land suitability index value, the weighting of each sub-criteria is also very necessary. Weighting is important because the importance level's of each sub-criteria is different. The weightings of each sub-criteria is calculated to determine how much the interest rate of criteria of the land suitability of soybean crop. AHP is a very popular method of weighting that used in the assessment of the land suitability and also has been proven as an effective weight calculation model. It is because there is calculation of the consistency ratio in the calculation process. In addition, the AHP method is part of decision making multicriteria approach that can handle heterogeneous data like in land suitability assessment that require a lot of criteria in the calculation process. The process of calculating weight using AHP is assisted by eight experts of agriculture and soil scientists from BPTP Central Java, Indonesia. The opinion from eight experts in the form of weight would be included in the process of pairwise comparison. The differences of experts' opinion are certain. To unite the opinion, the geometric mean method is used to determine the average weight given by the eight experts. The weight of AHP successfully calculated and presented in Table 2. The result of the weight of each sub-criteria will be calculated with the value of standardization to generating a suitability index value were overlayed with a map for each sub-criteria (Figs. 7, 8, 9, 10, and 11) so that the map of land suitability for soybean crop has been successfully created (Fig. 12).

From the results of the weighting on Table 2 shows that the soil physical condition is the biggest factor affecting the growth and development of soybean crops that are based on the ranking indicates the importance of the soil type and texture have great weight. That's happens when measured by logic, soil is the basic media as a place to grow plants that it contains water and nutrients that are food for the plant itself. Additionally, different types of soil have different textures. Such as alluvial soil type, were has soft and clay texture that are very good to support the growing power of the soybean roots. In addition to soil conditions, climatic condition is too important as an indicator of water availability in the region. However, soybean plants tend to grow very well in areas with rainfall that is not too high (Singha and Swain, 2016).

From the result, AHP is an effective method of weighting and can be used in the determination of the weight of land suitability sub-criteria. That is proved by the Table 2. In addition to determining the most influential factor in accordance with real condition, the weighting that is supported with excellent level of consistency ratio that is 0.01. The result of consistency ratio is far from the value of 0.1 which is the maximum limit of a weighting can be said consistent. Meanwhile, the result of the study by (Wali et al., 2016; 16, Deng et al., 2014) also stated that the method of AHP succeed in weighting.

However, AHP still has weaknesses, such as it is subjective because it is based on expert opinion. That weakness can be covered by using fuzzy method in land suitability for soybean crop. It can reduce the element of subjectivity of the results.

In this work, the result of suitability assessment for soybean tested with the correlation between the level of suitability with the soybean yield at field. The aim of this test is to investigate how much the suitability of system can made with the real condition in the field. And also to know the extent of the effectiveness of system made using Fuzzy sets and AHP compared to using conventional methods. For the data, suitability test is done in each district of the two different maps that are map of land suitability for soybean by BPTP in 2014 (Samijan, 2014) and map of land suitability for soybean made by fuzzy sets method and AHP. In making the land suitability map of soybean by BPTP in 2014 (Samijan, 2014) they used the conventional method where there is no calculation in both the scoring and weighting. In other word the map-making process is carried out manually were only based on the study of FAO 1976 for the classification of land suitability classes. For the correlation data, it is come from the data of soybean productivity every district in the Kebumen Regency from 2011-2015 that we obtained from Indonesia's National Statistical Agency. The data of soybean productivity we classified into three classes: very good (>2 ton/ha), good enough (1−2 ton/ha), and less well (<1 ton/ha). The classification is based on the average productivity of some varieties of soybean in Indonesia that reach 2 ton/ha. We assumed that, if 1 ha of soybean land is able to produce more than the average yield of 2 ton or more, it means the land has excellent suitability (S1) to grow the soybeans. If the land is able to produce 1−2 ton/ha, the land condition is quite good (S2) to grow the soybean. And if it is only able to produce soybean <1 ton/ha land is less well (S3-N) for the soybean crop. The result of the comparison test of the correlation map of land suitability for soybean with soybean productivity levels presented in Fig. 13.

The result test of the proposed model obtained by two subdistricts in Kebumen Regency which has a mismatch between the characteristics of the condition of land with soybean productivity. That two areas are Ayah sub-district and Puring sub-district. For the ayah sub-district, it does not accordance to the soybean crop for the overall condition. It is because this area is dominated by limestone mountain with steep slope condition and coarse soil texture which are not suitable for agriculture. Calcareous soil type is dominate although there are some areas that have suitable soil types condition for soybean crop. Action field studies is needed to see the condition of agriculture in the region. It aims to determine the actual location of soybean planting. However, as many as 24 sub-districts identified as having suitable condition with the existing productivity data. As for the result test from the conventional model by BPTP, only identified 23 regions that match the existing field condition. So that, for land suitability map of soybean crop from the proposed model based on Fuzzy sets and AHP (Fig. 13(a)) has a correlation rate of 92.30% better than the level of
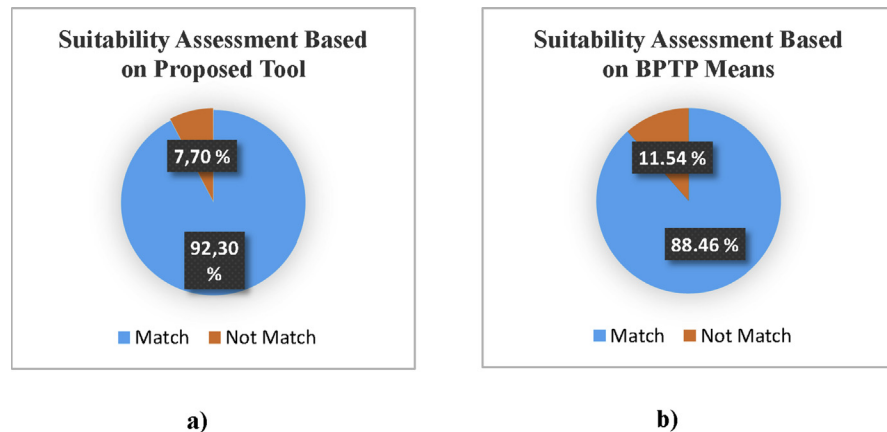
Fig. 13. Comparison of productivity correlation level of between the (a) suitability assessment based on proposed tool and (b) suitability assessment based on BPTP means.

correlation of the land suitability map of soybean crop from BPTP which is using conventional methods (Fig. 13(b)). The correlation of result test showed that the application of Fuzzy set and AHP for land suitability assessment of soybean plant has closer conformity with the real condition. It proves that the fuzzy set and AHP are an effective model for land suitability assessment to support the decision. In addition, from the result accuracy of the suitability assessment based on fuzzy set and AHP, it can replace the conventional method which is still used in some cases. The advantages of the proposed tool based on fuzzy set and AHP in the suitability assessment of soybean crop is the calculation process of standardization sub-criteria and weighting process of sub-criteria was carried out based on systematic calculation algorithm. Thus, it can produce the results that which is not subjectively rather than the conventional method which is based on expert opinion without a certain calculation process.

5. Conclusion

Land suitability assessment for soybean crops in Kebumen District has been successfully established by integrating GIS, Fuzzy sets and AHP methods. This method is applied to be able to replace manual scoring methods that are still applied in several studies. The standardization of the sub-criteria is performed by integrating the fuzzy membership function (Mfs (xi)) aimed at converting numerical values to various magnitudes on the sub-criteria to the level of membership function in the range $0-1$. In this study, fuzzy membership function calculations on fuzzy sets have a systematic and appropriate mechanism to determine the standardization value of sub-criteria. Meanwhile, AHP is integrated into the process of determining the weight of each sub criteria used. AHP weighting process is effective for determining the weighting value of the sub-criteria in a systematic way and the consistency of ratios can be measured. Therefore, the weighting of experts can be accepted on the basis of a good calculation process. The standardization value of the calculation of $Mfs_{(xi)}$

and the weight of AHP (W_i) is calculated to produce a Land Suitability Index (S_i). The results showed that from 132,872.9 ha the land in Kebumen Regency has 81.42% is appropriate, 11.25% is marginal and 7.33% is not suitable. From the appraisal process has been tested the correlation level of conformity with soybean productivity and yield at the correlation level at 92.30%. The correlation result is better than correlation level obtained from land suitability map for soybean from BPTP which only 88,46%. Thus, it can be argued that the application of the Fuzzy set and AHP method in assessing the suitability of soil for soybean crops has better accuracy. The integration of fuzzy sets and AHP is a good and powerful combination of techniques to be recommended replacing conventional land suitability assessment methods. As well, from the correlation of accuracy indicates that the proposed tool based on Fuzzy sets and AHP techniques can be used as a basis for agricultural planning to optimize soybean production.

Declarations

Author contribution statement

Subiyanto; Hermanto: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ulfah Mediaty Arief: Analyzed and interpreted the data; Wrote the paper.

Ahmad Yazidun Nafi: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Funding statement

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

participating has helped in the process of weighting the sub-criteria and are also on the data related to the study.

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