Optimization of Group Decision Support System in Updated Pranata Mangsa System Using Fuzzy Multi Criteria Decision Making (FMCDM) Method

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Abstract

Farmers have used a natural phenomenon as an indicator of planting pattern arrangement in the form of local knowledge of pranata mangsa, however, the accuracy level of traditional prediction is frequently biased nowadays, hence requiring a model to assist agriculture department, agricultural extension workers and farmers in decision making of an effective planting pattern determination. In order to respond this matter, Fuzzy Multi Criteria Decision Making (FMCDM) and triangular fuzzy number methods with 19 sub-districts in Boyolali as land alternatives, 3 climate criteria and 3 decision makers would be applied. The alternative commodities consist of rice, corn and soybeans.
The result shows that rice is compatible in Banyudono, Mojosongo, Ngemplak and Boyolali with value of 0.3; while corn is compatible in Sambi, Teras, Sawit and Banyudono with value of 0.55; and soybean is compatible in Teras, Sawit and Sambidengan with value of 0.36. The advantage of this study is as an innovation of soft computing technology in agriculture and used as a decision making proponent.

Keywords : *fuzzy multi criteria decision making, gdss, planting pattern, pranatamangsa*

1. Introduction

The decision making matter plays significant roles in many aspects of life [1]. There are several conditions that are probably experienced by the decision maker when making any decision, namely [2] : (1) decision making in certainty, in which all alternatives are figured out, (2) decision making in some selected risk level, (3) decision making in uncertainty condition, including the alternative that is not obviously figure out.

MCDM is a method that can be used as a tool of supporting decision. *Multicriteria Decision Making Methods* (MCDM) refers to the process of *screening, prioritizing, ranking* or choosing an alternative set with criteria conditions of *independent, incommensurate* or *conflicting* [3]. MCDM is very appropriate to be implemented in all alternative cases, containing some criteria of which each has nominal value. Each criterion has quality that can be applied as comparison tool. MCDM assumed that alternative rating and quality of criteria are regarded as *crips.* Not all cases, however, accomplished the assumption; hence MCDM consideration is less proper and requiring some new considerations [4]. FMCDM is a decision making method considering some alternatives and criteria of a condition regarded as *fuzzy* [5].

The problem to be solved in this paper relates to the exploration of suitability of the proper areas for rice, corn and soybean commodities in Boyolali comprising 19 sub-districts. There are three plants that would be alternative plants, i.e. rice, corn and soybean. Criteria used as the condition of plant growth consist of temperature, rainfall and humidity. The result was supposed to gain the planting suitability pattern in sub-district areas that could be obtained in a quite prompt period by considering criteria and weights.

2. Related Works

GDSS was suggested to increase efficiency and effectivity of the decision maker regarding the active role in making decision without any compulsion in

giving decision [6]. Regarding some literatures indicating some stages that needed to take to apply FMCDM, Cahyo and Wahyuni [5] agreed with Chou[7], Lee, Wang &Pang[8], Haarstrick and Lazarevska[9]. These four journalist conveyed similar stages to Elanchezhian, Ramnath and Kesavan[10].

Those four articles conveyed stages of accomplishing FMCDM that supported each other. By adapting those four articles, the three stages of FMCDM process were required, i.e. problem representation, evaluation of *fuzzy* sets of every decision alternatives, and selection of the optimum alternatives.

3.   Theoretical Framework

Each plant has different growth conditions. Based on the 3 plants to be planted, rice can grow well in tropical and moist areas. The fine rainfall distribution for 4 months and the average of 200 mm per month or more, around 1500 – 2000 mm per year. The fine temperature for rice growth is 23°C. The appropriate altitude for rice is around 0 – 1500 m dpl. The fine land for rice growth is rice field land containing sand, dust and clay segments in certain ratio as well as requiring sufficient amount of water. Rice can grow well in the soil with the top layer of 18 – 22 cm thick and pH of 4 -7 [11].

Unlike rice, the disposed of climate for corn is mostly the temperate climate to humid subtropical climate. Corn can grow in the area with an altitude of 0 – 50°C LU up to 0 – 40°LS. In non-irrigated land, the plant growth requires ideal rainfall which is around 85 – 200 mm/ month and should be evenly spread. In the phase of flowering and grain-filling, corn needs to get enough water. Corn should be planted in the early season, just before the dry season. The corn growth requires sunlight. The growth of shaded corn would be hampered as well as the seed crops were not good enough, and the fruit could not grow properly. The disposed temperature of corn is around 21 - 34°C, in which the ideal plant growth requires optimum temperature around 23 - 27°C. The proper temperature of corn seed sprouting process is around 30°C. Corn harvest in the dry season would be better than wet season since influencing the ripening time and crops drying [12].

Meanwhile, soybean mostly grows in tropical and subtropical areas. Whether the climate is appropriate for corn, it can be used as a barometer of proper climate of soybean. The durability of soybean is better than corn indeed. The dry climate is more preferred to moist climate for soybean. Soybean can grow well in areas with rainfall of 100 – 400 mm/ months. Meanwhile, in order to get an optimal result, soybean requires rainfall of 100 – 200 mm/ month. The disposed temperature of soybean is around 21 – 34°C, however, the optimal temperature for soybean growth is around 23 – 27°C. The proper temperature of soybean seed sprouting process is around 30°C. Soybean harvest in a dry season would be better than wet season since influencing the seed ripening time and the yield drying [13].

This study employed Fuzzy MCDM method. *Multi Criteria Decision Making* is a method for assisting the decision making towards some decision alternatives which should be taken by considering some criteria [14]. A problem probably emerged in case there was uncertainty within the importance weights of each criterion and the degree of suitability of each alternative to each criterion [15]. The assessment given by the decision maker is conducted through qualitative and presented using linguistic way [16].

In Javanese culture, there is a science of weather and climate forecast which is called pranatamangsa. Pranatamangsa comes from the words 'pranata' which mean procedure and 'mangsa' which means season [17]. This culture is not only found in Java, but also in Bali which is called as Wariga as well as in Sunda that is called as Kala. Pranatamangsa that exists all along, mostly used theory based on socially economical of agriculture [18], however, along with the development of technology, the studies of pranatamangsa have been conducted by engaging the other fields of study, for instance, the studies conducted by Hartomo, Sediyono, Yulianto and Simanjutak [19] with an issue of pranatamangsa combined with Local Knowledge and Agro-meteorology using Fuzzy Logic to determine plant pattern as the improvement of the previous studies with Agro-meteorology-based using LVQ, MAP ALOV [20].

4.   Research Method

There are 4 activities conducted in this study: The first activity are choosing a set of rating for the criteria weights and the degree of suitability of each alternative and its criteria. Generally, sets of rating consist of 3 elements, i.e. linguistic variable (x) representing the criteria weights and the degree of suitability of each alternative and its criteria; $T(x)$ representing the rating of linguistic variable; and membership function relating to each element of

T(x). For instance, the rating for weight of Significant Variable of a criterion defined as: T(significant) = {VERY LOW, LOW, FAIR, HIGH, VERY HIGH}. After the determination of this set of rating was conducted, the membership function of each rating should be determined afterward. The triangle function is commonly used for it. For instance, W_t is the weight of C_t criterion; and S_{it} is fuzzy rating for the degree of suitability of A_i decision alternative and C_t criterion; as well as F_i is fuzzy suitability index of A_i alternative representing the degree of suitability of decision alternatives and decision criteria obtained from the aggregation result of S_{it} and W_t.

The second activity are evaluating the criteria weights and the degree of suitability of each alternative and its criteria.

The third activity is aggregating the criteria weights and the degree of suitability of each alternative and its criteria. There are some methods which can be used to aggregate the decision results of the decision makers, such as: mean, median, max, min, and combine operator. From those methods, mean is the most frequently used. Mean is the operator used for the adding and multiplication of fuzzy.

By using mean, F_i is formulated as:
$$F_t= \left(\tfrac{1}{k}\right)[(S_{t1}\otimes W_1) \oplus (S_{t2}\otimes W_2) \oplus \wedge \oplus (S_{tk}\otimes W_k)] \quad (1)$$

By substituting S_{it} and W_t with triangular fuzzy number, that is $S_{it} = (o_{it}, p_{it}, q_{it})$; and $W_{it} = a_t,b_t,c_t)$; F_t can be approached as:
$$F_i \cong (Y_i, Q_i, Z_i) \qquad (2)$$
With
$$Y_i= \left(\tfrac{1}{k}\right)\sum_{t=1}^{k}(o_{it},a_i) \qquad (3)$$
$$Q_i= \left(\tfrac{1}{k}\right)\sum_{t=1}^{k}(p_{it},b_i) \qquad (4)$$
$$Z_i= \left(\tfrac{1}{k}\right)\sum_{t=1}^{k}(q_{it},c_i) \qquad (5)$$
$$i=1,2,3,\dots,n.$$

The fourth activity is prioritizing the decision alternatives based on aggregation result. The priority of aggregation result was required regarding the ranking process of decision alternatives.

In order to determine the order of each alternative, the following equation can be engaged:
$$S_i= \sum_{j=1}^{n} r_{ij} \qquad (6)$$

A method of total integral value can be used. For instance, F is a triangular fuzzy number, F = (a, b, c), the total integral value can be formulated as follows:
$$I_T^{\alpha}(F)= \left(\tfrac{1}{2}\right)(\alpha c+b+ (1- \alpha)a) \qquad (7)$$

- α value is the optimism index representing the degree of optimism of decision makers ($0\leq\alpha\leq1$).
- In case α value is greater, indicating that the degree of optimism is greater, as well.
- Choosing the decision alternatives with the highest priority as the optimum alternative. The greater the Fi value indicates the biggest suitability of decision alternatives of decision criteria and this value would be the goal.

5. Architectural Design

Architectural model that is used in this study can be seen in figure 1. The study was conducted in 5 stages.

In stage 1, The Temperature, Rainfall and Humidity during 2001 – 2011 data of Boyolali that can be seen in boyolali in numbers collected, and pre-processing data was conducted afterwards.

Stage 2 comprises weighting process and value aggregation of the data result which has been conducted as well as the information of plant growth condition and input result from some plant experts.

Stage 3 comprises the process of sorting plant suitability toward an area.

Stage 4 comprises the process of searching the optimism value of the ranking result which has been conducted in the previous stage.

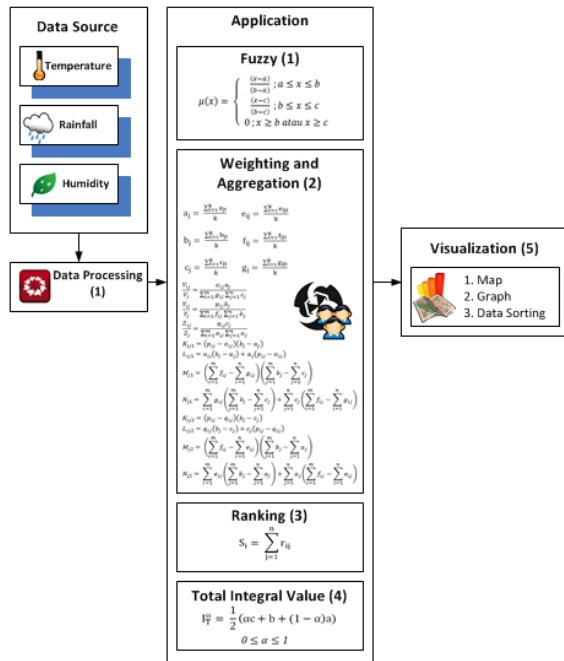Stage 5 comprises the stage of Visualization result of the study that has been conducted.

Fig 1. Architectural Model of the Study

The data processing was conducted using Excel. Subsequently, the following stages consist of classifying data, searching the minimum, maximum and quartile value of the data, charts or graphs using Mean, Median, Mode, Quartile, CCart, Plot, Piecewise functions of maple. The weighting, aggregation and ranking sections, the own function was generated, supported by the use of maple referring to the predefined equation. The last visualization used the function found in GUI package provided by maple.

6.   Experiment

Data were taken from Boyolali in Numbers during 2001 – 2011. In this study, 3 food plants (Rice, Corn and Soybean) would be searched for the compatibility of growing in certain areas and 19 alternatives of places to plant the 3 food plants, namely Selo, Ampel, Cepogo, Musuk, Boyolali, Mojosongo, Teras, Sawit, Banyudono, Sambi, Ngemplak, Nogosari, Simo, Karanggede, Klego, Andong, Kemusu, Wonosegoro, Juwangi sub-districts. Besides, 3 criteria (indications) of decision making consist of temperature; rainfall; humidity and 3 decision makers comprise D1, D2 and D3 who have expertise and proficiency in plant growth conditions.
By using equation 8 :

$$A = \{Ai \mid i=1,2,\dots,n\} \qquad (8)$$

determined that 19 alternatives of plant areas comprise A = {A1,A2,A, ..., A19}, in which A1=Selo, A2=Ampel, A3=Cepogo, A4=Musuk, A5=Boyolali, A6=Mojosongo, A7=Teras, A8=Sawit, A9=Banyudono, A10=Sambi, A11=Ngemplak, A12=Nogosari, A13=Simo, A14=Karanggede, A15=Klego, A16=Andong, A17= Kemusu, A18=Wonosegoro, A19=Juwangi. Besides, by using equation 9 :

$$C = \{Ct \mid t=1,2,\dots,k\} \qquad (9)$$

determined that 3 criteria (indications) of decision are C ={C1,C2,C3}

Linguistic variables representing importance weights of each criterion are T(importance) W1 = {SR, R, C, T, ST} in which SR=Very Low, R=Low, C=Fair, T=High, ST=Very High} by arranging membership function based on the expert's data that were processed to be fuzzy system. The membership function was taken from the ground data (Boyolali in 2001 – 2011). The data identification converted to linguistic and crisp input can be seen as follows.

6.1. Membership Function

In this stage, membership function of triangle comprising rainfall, temperature and humidity was created. Moreover, the way of determining fuzzy number membership used minimum, quartile and maximum value of the obtained data.
1. Temperature
    Based on the temperature data in 2001-2011 as shown in figure 2, the plan used triangular fuzzy number. It can be seen in fuzzy graph of temperature in figure 2 as follows.
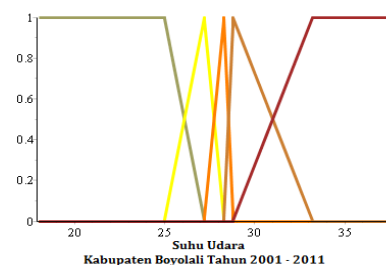

Fig 2. Fuzzy graph of temperature.

2. Humidity
    By using data in 2001-2011 as shown in figure 3, a set of fuzzy numbers of humidity using fuzzy triangle was acquired. The humidity graph can be seen in figure 3 as follows.

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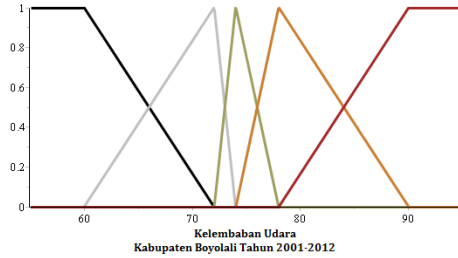ISSN (Print): 1694-0814 | ISSN (Online): 1694-0784
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Fig 3. Fuzzy graph of temperature

3. Rainfall

By using data in 2001-2011 as shown in figure 4, a set of the fuzzy number of rainfall using fuzzy triangle was acquired. The fuzzy graph of rainfall can be seen in figure 4 as follows.
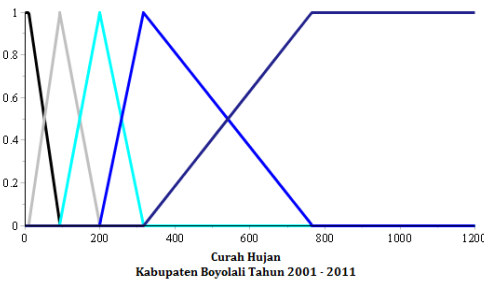

Fig 4. Fuzzy graph of rainfall

6.2. Degree of Suitability

Degree of suitability of alternatives and decision criteria comprise: T(suitability) S= {SK, K, C, B, SB}, in which SK = Very Little; K = Less; C = Fair; B = Good; SB = Very Good; in which each of them was represented with triangular *fuzzy* number as follows:

SK = (0.00, 0.00, 0.25)
K = (0.00, 0.25, 0.50)
C = (0.25, 0.50, 0.75)
B = (0.50, 0.75, 1.00)
SB = (0.75, 1.00, 1.00)

In the following stage, the decision makers gave weight for every criterion of each food plant and rating for the alternatives of each criterion, as well. The average weight of each criterion for the decision makers of each planting was accomplished by using equations of:

$$a_j = \frac{\sum_{t=1}^{k} a_{jt}}{k} \tag{10}$$

$$b_j = \frac{\sum_{t=1}^{k} b_{jt}}{k} \tag{11}$$

$$c_j = \frac{\sum_{t=1}^{k} c_{jt}}{k} \tag{12}$$

The equations above were used to sum *crisp* value of the decision result determined by the decision maker

based on the value of importance weights of each criterion. It was then divided with the total of decision makers, for instance, the calculation of the importance weight average of rice; in which the calculation can be seen as follows:

$$a_1 = \frac{0.50+0.25+0.50}{3} = 0.4167$$

$$b_1 = \frac{0.75+0.50+0.75}{3} = 0.6667$$

$$c_1 = \frac{0.10+0.75+0.10}{3} = 0.9167$$

Thus, the whole determination of the importance weight average of rice, corn, and soybean can be seen in table 1, 2 and 3 as follows:

Table 1. Weight of criteria of rice planting decision maker.

Kriteria	Pengambil Keputusan			Crisp
	D1	D2	D3	
C1 = Suhu Udara	T	C	T	0.4167, 0.6667, 0.9167
C2 = Kelembaban	T	T	T	0.5000, 0.7500, 1.0000
C3 = Curah Hujan	R	C	T	0.2500, 0.5000, 0.7500

Table 2. Weight of criteria of corn planting decision maker.

Kriteria	Pengambil Keputusan			Crisp
	D1	D2	D3	
C1 = Suhu Udara	T	ST	T	0.5833, 0.8333, 1.0000
C2 = Kelembaban	T	ST	T	0.5833, 0.8333, 1.0000
C3 = Curah Hujan	T	ST	T	0.5833, 0.8333, 1.0000

Table 3. Weight of criteria of soybean planting decision maker.

Kriteria	Pengambil Keputusan			Crisp
	D1	D2	D3	
C1 = Suhu Udara	T	C	C	0.3333, 0.5833, 0.8333
C2 = Kelembaban	T	C	T	0.4167, 0.6667, 0.9167
C3 = Curah Hujan	T	C	T	0.4167, 0.6667, 0.9167

After the decision maker inputted the weights, the average weight of the alternatives of each criterion of rice, corn and soybean referred to equations of:

$$e_{ij} = \frac{\sum_{t=1}^{k} a_{ijt}}{k} \tag{13}$$

$$f_{ij} = \frac{\sum_{t=1}^{k} f_{ijt}}{k} \tag{14}$$

$$g_{ij} = \frac{\sum_{t=1}^{k} g_{ijt}}{k} \tag{15}$$

The equations above were used to add up *crisp* value of predefined decision of the decision maker based on linguistic value of the degree of suitability of the alternatives and each decision criterion. It was then divided with the total of decision makers.
The calculation of alternative 1-Selo with criterion 1-Temperature was figured out as follows:

$$e_{11} = \frac{0.00+0.00+0.00}{3} = 0.0000$$

$$f_{11} = \frac{0.00+0.00+0.00}{3} = 0.0000$$

$$g_{11} = \frac{0.25+0.25+0.25}{3} = 0.2500$$

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The calculations above were applied to 19 sub-districts alternatives with 3 determined criteria. The excerpt of rice calculation data was portrayed in Table 4.

Table 4. The excerpt of the average weight calculation data of the alternatives of each criterion.

Kriteria	Alter natif	Pengambil Keputusan			Bobot rata-rata		
		D1	D2	D3			
C1= Suhu Udara	A1	SK	SK	SK	0.0000	0.0000	0.2500
	A2	K	C	K	0.0833	0.3333	0.5833
	A3	K	K	K	0.0000	0.2500	0.5000
	…	…	…	…	…	…	…
	A17	C	SB	B	0.5000	0.7500	0.9167
	A18	C	SB	B	0.5000	0.7500	0.9167
	A19	C	SB	B	0.5000	0.7500	0.9167
C2= Kelembaban Udara	A1	SB	B	C	0.5000	0.7500	0.9167
	A2	B	C	C	0.3333	0.5833	0.8333
	A3	B	B	C	0.4167	0.6667	0.9167
	…	…	…	…	…	…	…
	A17	C	K	B	0.2500	0.5000	0.7500
	A18	C	K	B	0.2500	0.5000	0.7500
	A19	C	K	B	0.2500	0.5000	0.7500
C3= Curah Hujan	A1	SB	B	C	0.5000	0.7500	0.9167
	A2	SB	C	C	0.4167	0.6667	0.8333
	A3	SB	C	C	0.4167	0.6667	0.8333
	…	…	…	…	…	…	…
	A17	C	K	B	0.2500	0.5000	0.7500
	A18	C	K	B	0.2500	0.5000	0.7500
	A19	C	K	B	0.2500	0.5000	0.7500

Likewise for corn and soybean, the calculations above were repeated to calculate the average weight of each decision criterion of the decision result taken by the decision maker. Subsequently, the following stage was conducted by determining the average value of each alternative based on the given criteria using the following equations:

$$\frac{V_{ij}}{V_j} = \frac{o_{ij}a_j}{\sum_{i=1}^{m} g_{ij} \sum_{j=1}^{n} c_j} \tag{16}$$

$$\frac{Y_{ij}}{Y_j} = \frac{p_{ij}b_j}{\sum_{i=1}^{m} f_{ij} \sum_{j=1}^{n} b_j} \tag{17}$$

$$\frac{Z_{ij}}{Z_j} = \frac{q_{ij}c_j}{\sum_{i=1}^{m} e_{ij} \sum_{j=1}^{n} a_j} \tag{18}$$

The equations above were used to multiply criteria degree of alternatives and degree of suitability of decision alternatives at the same criteria. It was then divided with the sum of all alternatives determined by the first decision maker at the same criteria and multiplied with the sum of the average weight of criteria determined by the 3rd decision maker. The calculation was portrayed as follows:

$$\frac{V_{11}}{V_1} = \frac{0.0000 \cdot 0.3333}{15.5833 \cdot 2.6667} = 0.0000$$

$$\frac{Y_{11}}{Y_1} = \frac{0.1667 \cdot 0.5833}{10.8333 \cdot 1.9167} = 0.01720$$

$$\frac{Z_{11}}{Z_1} = \frac{0.4167 \cdot 0.8333}{6.1667 \cdot 1.1667} = 0.6569$$

Equation 16 to 18 was used to determine alternative rating of the decision maker for each criterion.

$$K_{ij1} = \left(p_{ij}-o_{ij}\right)\left(b_j-a_j\right) \tag{19}$$

Equation 19 was used to seek the deviation of the average weight of the degree of suitability for the 2nd and 1st decision maker. It was then multiplied with the deviation of the criteria weight determined by the 2nd and 1st decision maker. The calculation example of the equation was shown as follows:

$K_{111} = (0.1667-0.0000)\cdot(0.5833-0.3333)$
$K_{111} = (0.1667)\cdot(0.2500)$
$K_{111} = 0.04167$

The equation above was repeated for the determined 19 alternatives and 3 criteria.

$$L_{ij1} = o_{ij}\left(b_j-a_j\right)+a_j\left(p_{ij}-o_{ij}\right) \tag{20}$$

Equation 20 was used to multiply the degree of suitability of the alternatives to the criteria of decision maker 1 and the deviation of the criteria weight determined by the decision maker 2 and 1. It was then added with the multiplication result of the criteria weight of the decision maker 1 and the deviation of the degree of suitability of the alternatives to the criteria determined by the decision maker 2 and 1 at the same criteria. The calculation example of the equation was shown as follows:

$L_{111} = 0.0000(0.5833-0.3333)+0.3333(0.1667-0.0000)$
$L_{111} = 0.0000+0.05556$
$L_{111} = 0.05556$

$$M_{j1} = \left(\sum_{i=1}^{m} f_{ij} - \sum_{i=1}^{n} g_{ij}\right)\left(\sum_{j=1}^{m} b_j - \sum_{j=1}^{n} c_j\right) \tag{21}$$

Equation 21 was used to multiply the deviation of the sum of degree of suitability of alternatives to the criteria determined by the decision maker 2 and 3 and the criteria weight determined by the decision maker 3 and 2. The calculation example of the equation was portrayed as follows:

$M_{11} = (10.8333-15.5833)\cdot(1.9167-2.6667)$
$M_{11} = (-4.7500)\cdot(-0.7500)$
$M_{11} = 3.5625$

$$N_{j1} = \sum_{i=1}^{m} g_{ij}\left(\sum_{j=1}^{m} b_j - \sum_{j=1}^{n} c_j\right)+\sum_{j=1}^{n} c_j \cdot \left(\sum_{i=1}^{m} f_{ij} - \sum_{i=1}^{n} g_{ij}\right) \tag{22}$$

Equation 22 was used to calculate the multiplication of the total number of degree of suitability of alternatives to the criteria determined by the decision maker 3 and the deviation of the criteria weight determined by the decision maker 2 and 3. It was then added with the criteria weight result determined by the decision maker 3 and multiplied with the deviation of the total number of degree of suitability of alternatives to the criteria determined by the decision maker 3 and 2. The calculation example of the equation was portrayed as follows:

$N_{11} = 15.5833\cdot(1.9167-2.6667)+2.6667\cdot(10.8333-15.5833)$
$N_{11} = 15.5833\cdot(-0.7500)+2.6667\cdot(-4.7500)$
$N_{11} = -11.6875+(-12.6668)$
$N_{11} = -24.35417$

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$$K_{ij2}=\left(p_{ij}-q_{ij}\right)\left(b_j-c_j\right) \qquad (23)$$

Equation 23 was used to seek the deviation of the average weight of degree of suitability for the 2nd and 3rd decision maker. It was then multiplied with the deviation of the criteria weight determined by the 2nd and 3rd decision maker. The calculation example of the equation was portrayed as follows:

$K_{112}=(0.1667-0.4167)\cdot(0.5833-0.8333)$

$K_{112}=(-0.2500)\cdot(-0.2500)$

$K_{112}=0.0625$

$$L_{ij2}=q_{ij}\left(b_j-c_j\right)+c_j\left(p_{ij}-q_{ij}\right) \qquad (24)$$

Equation 24 was used to multiply the degree of suitability of alternatives to the criteria of the decision maker 3 and multiplied with the deviation of the criteria weight determined by the decision maker 2 and 3. It was then added with the multiplication result of the criteria weight of the decision maker 3 and the deviation of degree of suitability of alternatives to the criteria determined by the decision maker 2 and 3 at the same criteria. The calculation example of the equation was portrayed as follows:

$L_{112}=0.4167\cdot(0.5833-0.8333)+0.8333\cdot(0.1667-0.4167)$

$L_{112}=-0.1042+(-0.2084)$

$L_{112}=-0.3126$

$$M_{j2}=\left(\sum_{i=1}^{m} f_{ij}-\sum_{i=1}^{n} e_{ij}\right)\left(\sum_{j=1}^{m} b_j-\sum_{j=1}^{n} a_j\right) \qquad (25)$$

Equation 25 was used to multiply the deviation of the sum of the degree of suitability of alternatives to the criteria determined by the decision maker 2 and 1 and the criteria weight determined by the decision maker 2 and 1. The calculation example of the equation was portrayed as follows:

$M_{12}=(10.8333-6.1667)\cdot(1.9167-1.1667)$

$M_{12}=(4.6666)\cdot(0.7500)$

$M_{12}=3.49995$

$$N_{j2}=\sum_{i=1}^{m} e_{ij}\left(\sum_{j=1}^{m} b_j-\sum_{j=1}^{n} a_j\right)+\sum_{j=1}^{n} a_j\left(\sum_{i=1}^{m} f_{ij}-\sum_{i=1}^{m} e_{ij}\right) \qquad (26)$$

Equation 26 was used to calculate the multiplication of the total number of degree of suitability of alternatives to the criteria determined by the decision maker 1 and the deviation of the criteria weight determined by the decision maker 2 and 1. It was then added with the result of criteria weight determined by the decision maker 1 and multiplied with the deviation of the total number of degree of suitability of alternatives to the criteria determined by the decision maker 2 and 1. The calculation example of the equation was portrayed as follows:

$N_{12}=6.1667\cdot(1.9167-1.1667)+1.1667\cdot(10.8333-6.1667)$

$N_{12}=6.1667\cdot(0.7500)+1.1667\cdot(4.6666)$

$N_{12}=4.6250+5.4445$

$N_{12}=10.069$

The calculation using equation 16 to 26 was repeated for the determined 19 Alternatives and 3 Criteria. The calculation of equation 13 – 26 was also conducted to corn and rice. Thus, the result was generated as in table 5.

Table 5. The excerpt of calculation data of soybean.

r_{ij}	V_{ij}/V_j	Y_{ij}/Y_j	Z_{ij}/Z_j	$K_{ij}1$	$L_{ij}1$	M_j1	N_j1	$K_{ij}2$	$L_{ij}2$	M_j2	N_j2
1	0.000	0.017	0.065	0.041	0.055	3.562	-24.354	1.000	-0.312	3.500	10.069
	0.019	0.066	0.165	0.062	0.166	3.562	-23.416	1.000	-0.416	3.562	9.166
	0.024	0.070	0.139	0.062	0.187	3.312	-22.965	0.667	-0.340	3.562	9.854
2	0.000	0.034	0.091	0.062	0.104	3.562	-24.354	1.000	-0.354	3.500	10.069
	0.019	0.066	0.165	0.062	0.166	3.562	-23.416	1.000	-0.416	3.562	9.166
	0.024	0.070	0.139	0.062	0.187	3.312	-22.965	0.667	-0.340	3.562	9.854
...	...	...	...	...	...	...	...	...	...	...	...
18	0.004	0.077	0.158	0.062	0.208	3.562	-24.354	1.000	-0.458	3.500	10.069
	0.006	0.044	0.129	0.062	0.125	3.562	-23.417	1.000	-0.375	3.562	9.166
	0.012	0.051	0.124	0.062	0.146	3.312	-22.965	1.000	-0.396	3.562	9.854
19	0.004	0.077	0.158	0.062	0.208	3.562	-24.354	1.000	-0.458	3.500	10.069
	0.006	0.044	0.129	0.062	0.125	3.562	-23.417	1.000	-0.375	3.562	9.166
	0.012	0.051	0.124	0.062	0.146	3.312	-22.965	1.000	-0.396	3.562	9.854

From all equations above, the calculation result that would be used as the basis for determining the suitability of alternatives of planting medium for rice, corn and soybean in Boyolali areas would be obtained.

6.3. Alternative Selection Using Total Integral Method

In the following process, the optimum alternative selection of 19 sub-districts to determine the compatible areas for planting rice, corn or soybean was conducted in order to determine the order of each alternative. After the average rating of alternatives based on the criteria was obtained, the optimism level with the value of $0 \leq \alpha \leq 1$ would be calculated using total integral method. The example can be seen as follows:

For $\alpha=0.0$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(0.00\cdot0.06569+0.01720+(1-0.00)\cdot0.00)$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(0.00+0.01720+0.0000)$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(0.01720)$

$I_T^0(F)=0.00860$

For $\alpha=0.5$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(0.50\cdot0.06569+0.01720+(1-0.50)\cdot0.00)$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(0.03285+0.01720+0.00)$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(0.050045)$

$I_T^0(F)=0.0250$

For $\alpha=1.0$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(1.00\cdot0.06569+0.01720+(1-1)\cdot0.00)$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(0.06569+0.01720+0.0000)$

$I_T^0(F)=\left(\dfrac{1}{2}\right)(0.08289)$

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$I_T^0(F)=0.041445$

After the calculation of 19 alternatives and 3 determined criteria was conducted, the result was figured out as shown in table 6.

Table 6. Calculation of optimism degree of soybean

Kecamatan	Nilai Total Integral		
	α=0.0	α=0.5	α=1.0
r11 = Klego	0.00860	0.02502	0.04145
r12	0.04302	0.07967	0.11631
r13	0.04791	0.07657	0.10524
r21 = Karanggede	0.01754	0.04036	0.06318
r22	0.04302	0.07967	0.11631
r23	0.04791	0.07657	0.10524
…	…	…	…
r181 = Wonosegoro	0.04071	0.07912	0.11753
r182	0.02545	0.05610	0.08676
r183	0.03156	0.05945	0.08735
r191 = Juwangi	0.04071	0.07912	0.11753
r192	0.02545	0.05610	0.08676
r193	0.03156	0.05945	0.08735

After the average result of each criterion of an alternative was obtained, equation 9 would be used to figure out the value of each alternative suitability to food plants. The calculation example was shown as follows:

For α=0.0
$S_{1=Selo}$=0.00860+0.04302+0.04791
$S_{1=Selo}$=0.09772

For α=0.5
$S_{1=Selo}$=0.02502+0.07967+0.07657
$S_{1=Selo}$=0.19468

For α=1.0
$S_{1=Selo}$=0.04145+0.11631+0.10524
$S_{1=Selo}$=0.29164

By using equation 9, the table of total integral value could be obtained as shown in table 7:

Table 7. Total integral value with optimism degree of 0.0, 0.5 and 1.0 in Boyolali for soybean.

Kecamatan	Nilai Total Integral		
	α=0.0	α=0.5	α=1.0
A1 = Selo	0.09953	0.18126	0.26299
A2 = Ampel	0.10847	0.19660	0.28473
A3 = Cepogo	0.10847	0.19660	0.28473
A4 = Musuk	0.10847	0.19660	0.28473
A5 = Boyolali	0.12652	0.22776	0.32900
A6 = Mojosongo	0.12652	0.22776	0.32900
A7 = Teras	0.14812	0.25779	0.36746
A8 = Sawit	0.14812	0.25779	0.36746
A9 = Banyudono	0.12237	0.22373	0.32509
A10 = Sambi	0.14812	0.25779	0.36746
A11 = Ngemplak	0.11358	0.21195	0.31031
A12 = Nogosari	0.13116	0.23551	0.33986
A13 = Simo	0.13579	0.24326	0.35073
A14 = Karanggede	0.12346	0.22874	0.33401
A15 = Klego	0.12346	0.22874	0.33401
A16 = Andong	0.09772	0.19468	0.29164
A17 = Kemusu	0.09772	0.19468	0.29164
A18 = Wonosegoro	0.09772	0.19468	0.29164
A19 = Juwangi	0.09772	0.19468	0.29164

After the calculation process, the following stage was conducted by sorting the data from the lowest number to the highest number with α=0.0 followed by α=0.5 and the last one is α=1.0. Thus, it generated the result as shown in table 8, 9 and 10.

Table 8. Alternative value of sub-districts/cities in Boyolali for rice after the sorted value.

Kecamatan	Nilai Total Integral		
	α=0.0	α=0.5	α=1.0
A15 = Klego	0.09182	0.18355	0.27528
A14 = Karanggede	0.09708	0.18860	0.28012
A13 = Simo	0.10226	0.19589	0.28953
A7 = Teras	0.10655	0.20027	0.29400
A12 = Nogosari	0.10765	0.20327	0.29889
A4 = Musuk	0.11261	0.20076	0.28890
A8 = Sawit	0.11291	0.21175	0.31059
A10 = Sambi	0.11291	0.21175	0.31059
A16 = Andong	0.11782	0.21782	0.31782
A2 = Ampel	0.11787	0.20923	0.30060
A3 = Cepogo	0.12291	0.21421	0.30550
A17 = Kemusu	0.12309	0.22288	0.32266
A18 = Wonosegoro	0.12309	0.22288	0.32266
A19 = Juwangi	0.12309	0.22288	0.32266
A1 = Selo	0.12409	0.20511	0.28613
A5 = Boyolali	0.12861	0.23258	0.33654
A6 = Mojosongo	0.12861	0.23258	0.33654
A9 = Banyudono	0.13892	0.24603	0.35314
A11 = Ngemplak	0.13892	0.24603	0.35314

Table 9. Alternative value of sub-districts/cities in Boyolali for corn after the values were sorted.

Kecamatan	Nilai Total Integral		
	α=0.0	α=0.5	α=1.0
A1 = Selo	0.15837	0.28797	0.41756
A2 = Ampel	0.16659	0.30154	0.43650
A3 = Cepogo	0.16659	0.30154	0.43650
A4 = Musuk	0.17983	0.31889	0.45796
A11 = Ngemplak	0.19948	0.35586	0.51223
A12 = Nogosari	0.19948	0.35586	0.51223
A13 = Simo	0.20770	0.36943	0.53117
A14 = Karanggede	0.20770	0.36943	0.53117
A15 = Klego	0.20770	0.36943	0.53117
A16 = Andong	0.20770	0.36943	0.53117
A17 = Kemusu	0.20770	0.36943	0.53117
A18 = Wonosegoro	0.20770	0.36943	0.53117
A19 = Juwangi	0.20770	0.36943	0.53117
A5 = Boyolali	0.20823	0.36111	0.51399
A6 = Mojosongo	0.20823	0.36111	0.51399

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A10 = Sambi	0.22467	0.38827	0.55186
A7 = Teras	0.22969	0.39203	0.55438
A8 = Sawit	0.22969	0.39203	0.55438
A9 = Banyudono	0.22969	0.39203	0.55438

Table 10. Alternative value of sub-districts/cities in Boyolali for soybean after the values were sorted.

Kecamatan	Nilai Total Integral		
	$\alpha=0.0$	$\alpha=0.5$	$\alpha=1.0$
A16 = Andong	0.09772	0.19468	0.29164
A17 = Kemusu	0.09772	0.19468	0.29164
A18 = Wonosegoro	0.09772	0.19468	0.29164
A19 = Juwangi	0.09772	0.19468	0.29164
A1 = Selo	0.09953	0.18126	0.26299
A2 = Ampel	0.10847	0.19660	0.28473
A3 = Cepogo	0.10847	0.19660	0.28473
A4 = Musuk	0.10847	0.19660	0.28473
A11 = Ngemplak	0.11358	0.21195	0.31031
A9 = Banyudono	0.12237	0.22373	0.32509
A14 = Karanggede	0.12346	0.22874	0.33401
A15 = Klego	0.12346	0.22874	0.33401
A5 = Boyolali	0.12652	0.22776	0.32900
A6 = Mojosongo	0.12652	0.22776	0.32900
A12 = Nogosari	0.13116	0.23551	0.33986
A13 = Simo	0.13579	0.24326	0.35073
A7 = Teras	0.14812	0.25779	0.36746
A8 = Sawit	0.14812	0.25779	0.36746
A10 = Sambi	0.14812	0.25779	0.36746

The bigger the α value, the higher the plant suitability level for those areas was. Furthermore, the smaller the value or in the top order, the lower the plant suitability level for those areas was. Thus, the most compatible areas for rice commodity comprise Ngemplak, Sawit, Teras Sambi, Juwangi, Wonosegoro, and incompatible for Selo, Ampel, Cepogo, Musuk. Besides, the most compatible areas for corn commodity comprise Banyudono, Sawit, Teras, Sambi, Juwangi, Wonosegoro, and incompatible for Selo, Ampel, Cepogo, Musuk, Ngemplak. Otherwise, the most compatible areas for soybean commodity comprise Sambi, Sawit, Teras, Simo, Nogosari and incompatible for Selo, Andong, Kemusu, Wonosegoro, Juwangi.

7. Conclusion and Future Work

From the result of the study above, it can be concluded that the most appropriate areas for rice commodity consist of Ngemplak, Sawit, Teras Sambi, Juwangi, Wonosegoro. Otherwise, the inappropriate areas comprise Selo, Ampel, Cepogo, Musuk. Besides, the most appropriate areas for corn commodity consist of Banyudono, Sawit, Teras, Sambi, Juwangi, Wonosegoro. Otherwise, the inappropriate areas comprise Selo, Ampel, Cepogo, Musuk, Ngemplak. Moreover, the most appropriate areas for soybean commodity consist of Sambi, Sawit, Teras, Simo, Nogosari. Otherwise, the inappropriate areas comprise Selo, Andong, Kemusu, Wonosegoro, Juwangi.

As a suggestion for the improvement of future study, the data providing is supposed to be better. Thus, the calculation result should be visualized in form of map.

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