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Fuzzy Decision Support Model for Determining Plants Planted in Specific Suitable Areas in Indonesia

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ABSTRACT

This study is discussing a construction of decision support model (DSM) to fit plant types with specific area. The model uses the fuzzy logic method as a basis for calculations in choosing the right plants to be planted in certain areas and can reduce the risk of loss due to incorrect selection of plants. DSM works by analyzing the ecological and economic values inherent in soil and plant variables. In the analysis of ecological values, starting with the use of the fuzzy logic method for parameterizing to get a crisp value, then proceed with calculating the Euclidean value to get the minimum distance between the parameters of the soil variable of an area with plant variables that can be planted. Continue to economic analysis by calculating the value of optimization. Fuzzy can be used to convey information from ambiguous data. Taking into account the parameters that can be produced suitable plants in terms of ecology; namely rainfall, humidity, temperature, altitude/height, and sunshine; and economic aspects, namely the consistency of market prices for areas Surabaya, Sulawesi South, Central Kalimantan, East Kalimantan, and Banten.

Key words: decision support model, Euclidean, fuzzy logic, plant, Indonesia.

1. INTRODUCTION

Every natural resource is a very important component of an ecosystem in maintaining the balance of nature. Each component of the ecosystem interacts harmoniously with each other, so disruption of one component can cause changes in the ecosystem. In this research, plants (e.g. vegetables) have important ecological value for the earth; such as the lungs of the earth, maintain global climate stability, and help reduce the level of air pollution, and reduce the greenhouse effect. In addition, plants are producers of organic substances and oxygen, which are needed by other organisms. Plants can also form topsoil, store groundwater, and prevent erosion. Economically, this type of vegetable plant has a high economic value. These vegetables can be traded both domestically and for export as a form of economic activity.

Often many individuals experience failure in growing vegetables in their home environment. With different geographies in Indonesia, sometimes plants do not match the environment. Therefore, individuals in certain regions need a system that helps them in determining what types of plants are suitable in their area. With this system, it is expected that every individual who wants to grow crops can reduce losses due to failure to plant crops in his area. This system is very helpful especially for farmers who want to grow crops in their gardens, because they can choose the right type of plant in their area which has temperature, altitude, or soil type in the area. With this system, for farmers it can be facilitated because it can also minimize crop failure.

2. RESEARCH METHODOLOGY

Fuzzy logic is a method of calculating mathematics to be used with uncertainty values in various fields. Fuzzy logic has an important role in its application to complex phenomena and is not easily explained by mathematical methods, especially when the aim is to find a good approach solution [1][2]. We chose the Fuzzy set because it proved to be the leading way to solve decision problems, where the information available was subjective and clear [3].

The process of data collection is done by quantitative techniques, namely by first analyzing the middle value of the existing value range. The parameters are divided into five fuzzy forms in ecological parameters and one non-fuzzy form in economic parameters. The ecological parameters are rainfall, humidity, temperature, height, and sunshine. Then, the economic parameter is a market price consistency [4].

The first step taken in this research is to collect data about these parameters from each region studied and the consistency of market prices as economic parameters of the region or plants. The data are mostly coming from the Indonesia central statistics agency (ICSA) [5]. The types of plants operated as research objects consist of six types of plants (i.e. spinach, tomato, shallot, garlic, cabbage, and pepper). The regions functioned as the object of research are six provinces in Indonesia; i.e. East Java (EJ), South Sulawesi (SS), Central Kalimantan (CK), East Kalimantan (EK), Banten (B), and West Java (WJ).

The second step is to construct the model. By using fuzzy logic and Euclidean distance calculation [6], the model is successfully developed. The distance value is a value functioned to determine the decision. The value depicts a similarity between region and type of plant. It indicates that the lowest value denotes the most fitness, it means the plants has the most proper region to grow.

3. CONSTRUCTED MODEL

3.1 High Level Model Configuration

The constructed model consists of five components; Plant, Region, Fuzzy Logic, Euclidean, Comparison, and Dashboard. Components Plant and Region (with specific attributes) contributes real data to the model practically. The data converted to become more precise via the component Fuzzy Logic; where it produces a crisp output (CO) operated to calculate similarity (distance). The distance calculation is done in the component Euclidean. Similarity value are operated to be compared and prioritized. Then, all results are published in dashboard in several forms and presentation.

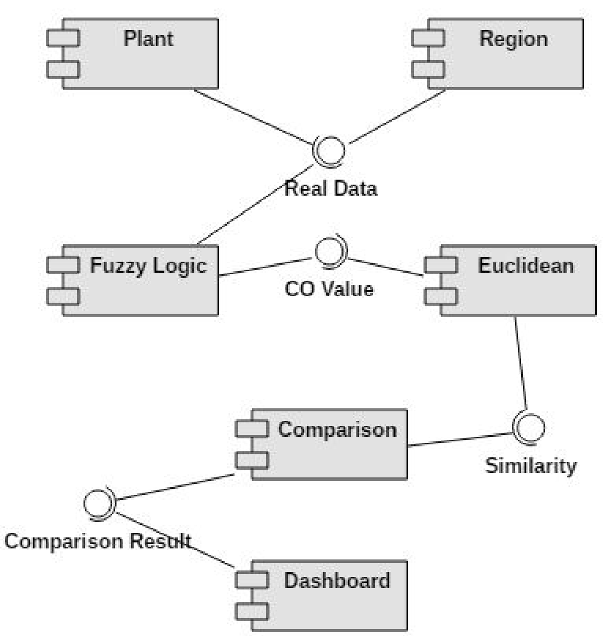

Figure 1: Component Diagram of the Constructed Model

3.2 Price Consistency Calculating Model

Market prices consistency is calculated to find out how much increases or decreases in crop prices on the market each year. In this study, we took data on average market prices over a 5-year period of 2008-2012 in each region in Indonesia. Table 1 until Table 6 show the result of price consistency calculation for each commodity (plant) respectively spinach, tomato, shallot, garlic, cabbage, and pepper. The fundamental equation for calculating it is showed in equation (1); where PC_j is a market price consistency for jth commodity, SP_i donates a starting price for ith year, FP_i symbolizes a final price for ith year, and n in this case is five.

$$PC_j = \frac{\sum_{i=1}^{n}((FP_i - SP_i)/(SP_i) \times 1}{n} \quad (1)$$

Table 1: Price Consistency for spinach

Region	2008	...		2012		Average
	Rupiah/bunch	...	...	Rupiah/bunch	%	%
EJ	1,498	...	...	3,600	17.26	24.90
SS	2,038	...	...	3,437	7.98	14.02
CK	2,227	...	...	3,984	-7.91	19.69
EK	4,803	...	...	5,165	13.72	2.31
B	1,915	...	...	2,619	3.35	8.56
WJ	1,795	...	...	2,418	4.86	7.78

Table 2: Price Consistency for Tomato

Region	2008	...		2012		Average
	Rupiah/Kg	...	...	Rupiah/Kg	%	%
EJ	2,279	...	...	7,535	5.95	37.70
SS	3,854	...	...	6,352	6.35	13.71
CK	4,493	...	...	4,600	-3.85	0.68
EK	5,527	...	...	7,433	16.20	8.95
B	2,782	...	...	4,693	10.61	14.25
WJ	2,120	...	...	5,786	18.13	30.64

Table 3: Price Consistency for Shallot

Region	2008	...		2012		Average
	Rupiah/Kg	...	...	Rupiah/Kg	%	%
EJ	7,861	...	...	7,550	0.41	-0.84
SS	9,659	...	...	7,572	-25.73	-4.74
CK	11,813	...	...	21,827	6.53	18.17
EK	11,492	...	...	12.490	-13.35	3.34
B	10,263	...	...	10.918	0.41	4.26
WJ	7,449	...	...	9,251	-6.35	5.83

Table 4: Price Consistency for Garlic

Region	2008	...		2012		Average
	Rupiah/Kg	...	...	Rupiah/Kg	%	%
EJ	3,276	...	...	6,571	-8.21	23.65
SS	6,876	...	...	9.667	-20.83	12.58
CK	-	...	...	10,435	-15.09	-0.58
EK	-	...	...	-	-	-
B	5,778	...	...	13,293	-2.52	25.84
WJ	5,579	...	...	9,569	10.00	15.73

Table 5: Price Consistency for Cabbage

Region	2008	...		2012		Average
	Rupiah/Kg	...	...	Rupiah/Kg	%	%
EJ	1,571	...	...	4,438	4.47	32.62
SS	1,976	...	...	2,713	11.51	8.37
CK	-	...	...	-	-	-
EK	5,233	...	...	8,931	3.25	15.08
B	-	...	...	1,302	0.00	-13.15
WJ	1,697	...	...	2,912	21.18	16.10

Table 6: Price Consistency for Pepper

Region	2008	...		2012		Average
	Rupiah/Kg	...	...	Rupiah/Kg	%	%
EJ	-	...	...	49,188	6.01	7.86
SS	36,201	...	...	52,050	12.34	10.04
CK	42,500	...	...	57,766	0.43	8.76
EK	50,521	...	...	54,047	11.10	2.98
B	36,323	...	...	43,932	5.34	5.09
WJ	38,071	...	...	54,179	6.77	9.30

Thus the basic data of value for ecological and price consistency parameter are represented in Table 7 and 8 respectively; where R, Hu, T, He, S are respectively rainfall, humidity, temperature, height, and sunshine. Moreover, the basic data of ecological parameter for each region is presented in Table 9.

Table 7: Ideal Crop Ecological Parameter Value (ICSA, 2017)

No.	Plants	Parameter				
		R	Hu	T	He	S
		(mm/y)	(%)	(^{O}C)	(m dpl)	(%)
1.	Spinach	2,000	55	28.5	1,000	65
2.	Tomato	900	60	20.0	500	65
3.	shallot	1,500	50	28.5	1,500	80
4.	Garlic	1,400	60	17.5	900	65
5.	Cabbage	2,500	55	22.5	1,500	65
6.	Pepper	2,500	55	28.5	250	65

Table 8: Crop Consistency Value of Market Prices for Each Regional Plant (ICSA, 2017)

No.	Plants	Market Price Consistency (%) for Each Region					
		EJ	SS	CK	EK	B	WJ
1.	Spinach	24.90	14.02	19.69	2.31	8.56	7.78
2.	Tomato	37.70	13.71	0.68	8.95	14.25	30.64
3.	shallot	-0.84	-4.74	18.17	3.34	4.26	5.83
4.	Garlic	23.65	12.58	0.58	0.00	25.84	15.73
5.	Cabbage	32.62	8.37	0.00	15.08	-13.15	16.10
6.	Pepper	7.86	10.04	8.76	2.96	5.09	9.30

Table 9: Regional data based on existing parameters (ICSA, 2017)

No.	Region/Province	Parameter				
		R	Hu	T	He	S
		(mm/y)	(%)	(^{O}C)	(m dpl)	(%)
1.	EJ	1,932	73.00	28.80	26.50	75.00
2.	SS	2,197	78.17	27.52	1,734.50	75.22
3.	CK	2,854	64.17	27.42	35.00	54.40
4.	EK	2,150	82.00	27.70	47.50	52.00
5.	B	1,310	79.30	27.30	500.00	65.06
6.	WJ	2,199	74.40	23.50	862.51	65.51

3.3 Fuzzy Logic Model

After getting the data that has been obtained, then make a set of fuzzy by looking for the middle value first so that it's easy to create a membership function. The membership function made successfully represented in Table 10; where FV is fuzzy variable (here ecological parameters determined as FV) and LV is linguistic variable. With the parameters, looking for value for each parameter domain from very low / low until high / very high is done. After getting the minimum and maximum value of the membership function domain, then making the middle value to be three membership function domain is conducted. Based on it, a graph is figured.

Table 10: Membership Function Value

FV	LV	Domain		MF Domain		
		Lowest	Highest	a	b	c
R	Very Low	50	1,050	50	550	1,050
	Low	950	1,950	950	1,450	1,950
	Medium	1,850	2,850	1,850	2,350	2,850
	High	2,750	3,750	2,750	3,250	3,750
	Very High	3,650	4,650	3,650	4,150	4,650
Hu	Low	0	50	0	25	50
	Medium	45	65	45	55	65
	High	60	100	60	80	100
T	Very Low	1	11	1	6	11
	Low	10	20	10	15	20
	Medium	19	29	19	24	29
	High	28	38	28	33	38
	Very High	37	47	37	42	47
He	Low	0	1,300	0	650	1,300
	Medium	2,500	4,000	2,500	3,250	4,000
	High	2,500	4,000	2,500	3,250	4,000
S	Low	0	50	0	25	50
	Medium	45	80	45	62.50	80
	High	75	100	75	87.50	100

The degree of membership is obtained by first making a graph of each of the parameters chosen. For chart data, it uses parameter data that has been obtained from the Central Statistics Agency (BPS) for each different parameter. Rainfall variable has 5 fuzzy sets, namely: very low, low, medium, high and very high. Humidity variable has three fuzzy set, namely: low, medium, and high. In the temperature variable there are 5 fuzzy sets, namely: very low, low, medium, high, and very high. Membership functions all defined via Table 11 until Table 15 and Figure 2 until Figure 6.

Table 11: Membership Function for Parameter Rainfall

LV	Shape	Points
Very Low (VL)	Trapezoid	0 ; 0 ; 550 ; 1050
Low (L)	Triangle	950 ; 1450 ; 1950
Medium (M)	Triangle	1850 ; 2350 ; 2850
High (H)	Triangle	2750 ; 3250 ; 3750
Very High (VH)	Trapezoid	3650 ; 4150 ; 4750 ; 4750

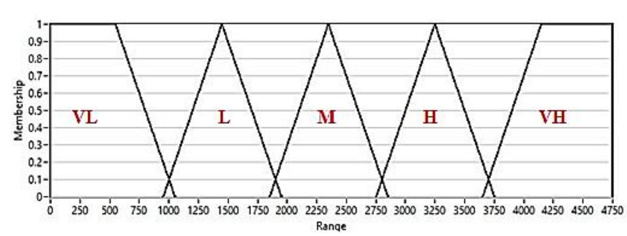

Figure 2: Membership Function for Parameter Rainfall

Table 12: Membership Function for Parameter Humidity

LV	Shape	Points
Low (L)	Trapezoid	0 ; 0 ; 25 ; 50
Medium (M)	Triangle	45 ; 55 ; 65
High (H)	Trapezoid	60 ; 80 ; 100 ; 100

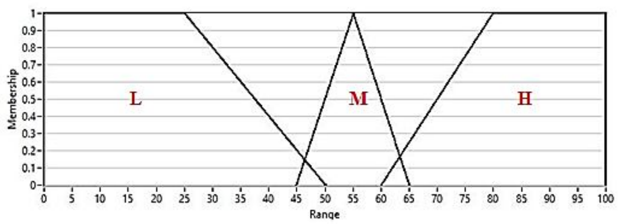

Figure 3: Membership Function for Parameter Humidity

Table 13: Membership Function for Parameter Temperature

LV	Shape	Points
Very Low (VL)	Trapezoid	0 ; 0 ; 6 ; 11
Low (L)	Triangle	10 ; 15 ; 20
Medium (M)	Triangle	19 ; 24 ; 29
High (H)	Triangle	28 ; 33 ; 38
Very High (VH)	Trapezoid	37 ; 42 ; 48 ; 48

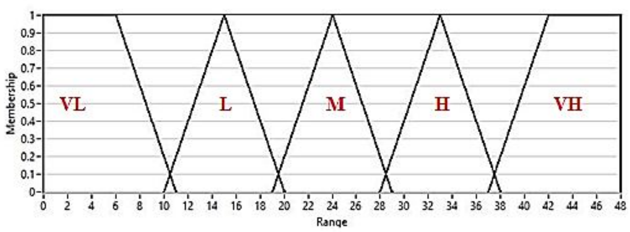

Figure 4. Membership Function for Parameter Temperature

Table 14: Membership Function for Parameter Land Height

LV	Shape	Points
Low (L)	Trapezoid	0 ; 0 ; 650 ; 1300
Medium (M)	Triangle	1200 ; 1900 ; 2600
High (H)	Trapezoid	2500 ; 3250 ; 4000 ; 4000

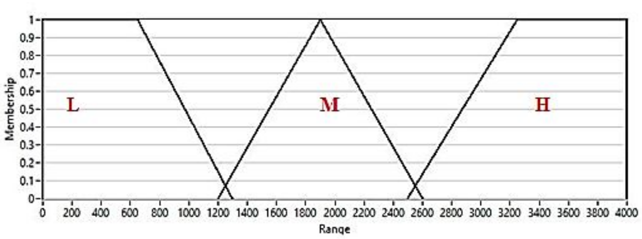

Figure 5: Membership Function for Parameter Temperature

Table 15: Membership Function for Parameter Sunshine

LV	Shape	Points
Low (L)	Trapezoid	0 ; 0 ; 25 ; 50
Medium (M)	Triangle	45 ; 62.5 ; 80
High (H)	Trapezoid	75 ; 87.5 ; 100 ; 100

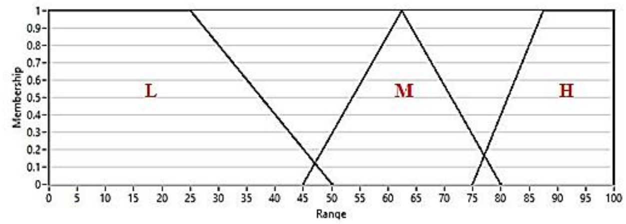

Figure 6: Membership Function for Parameter Temperature

One method that can be used to get membership values is through the approach of calculating the intersection value [4]. According to the value of existing parameters, they will be calculated to find the value of up-linear-representation and down-linear-representation. The up-linear line representation is presented in Figure 7, with equation (2) operated. Then, the down-linear line representation is configured in Figure 8, with equation (3) is executed technically. For specific triangular curve, the configuration is depicted in Figure 9, and the calculation is performed via equation (4).

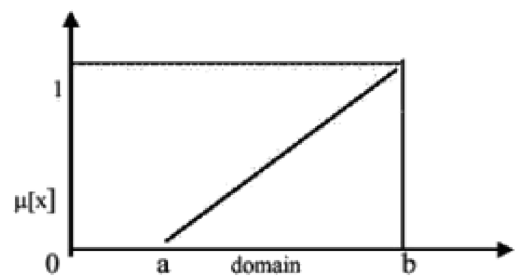

Figure 7: Representation of Up-Linear Line

$$\mu[x] = \begin{cases} 0; & x \leq a \\ (x-a)/(b-a); & a \leq x \leq b \\ 1; & x \geq b \end{cases} \quad (2)$$

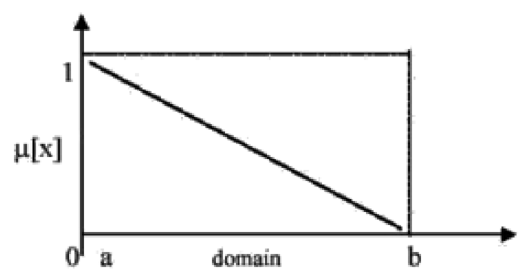

Figure 8: Representation of Down-Linear Line

$$\mu[x] = \begin{cases} 1; & x \leq a \\ (b-x)/(b-a); & a \leq x \leq b \\ 0; & x \geq b \end{cases} \quad (3)$$

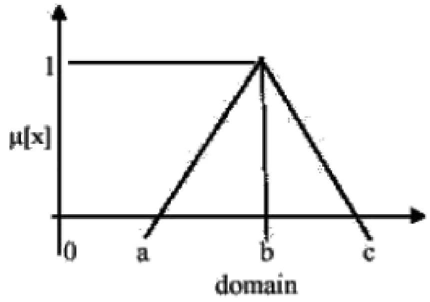

Figure 9: Representation of Triangular Curve

$$\mu[x] = \begin{cases} 0; & x \leq a \text{ or } x \geq c \\ (b-a)/(x-a); & a \leq x \leq b \\ (b-x)/(c-b); & b \leq x \leq c \end{cases} \quad (4)$$

Crisp value is produced to get the exact value, so that it can calculate the Euclidean value, where the Euclidean value can be used to find the final calculation results for the decision. A crisp output (CO) value is measured via equation (5); where x is a intersection point and y is a fuzzy centroid value.

$$CO = ((x_1 \times y_1) + (x_2 \times y_2))/(x_1 + x_2) \quad (5)$$

3.4 Euclidean Value Calculating Model

Euclidean value is a method of finding the proximity of two values of distance variables, in addition to easy this method also does not take time, and the process is fast. Euclidean is a heuristic function obtained based on direct distance free of obstacles such as to get the value of the length of the diagonal line on the triangle. But before getting the results both points must be represented in 2-dimensional coordinates (x, y) [6]. Euclidian value is obtained after finding the crisp value of each parameter and then using regional parameter data to be calculated, then calculated using the equation (6). From the results of that proficiency level has obtained Euclidian, then subsequently to produce the final result is used economic parameters namely price consistency. Determine the final results using the optimization method.

$$ED = \sqrt{\sum_{i=1}^{n} (x_{2i} - x_{1i})^2} \quad (6)$$

3.5 Optimizing Model

After finding the results of the Euclidian Value, then linked to economic parameters with price trends. Here two kinds of relative value are operated; maximum and minimum relative value (by using [7]). Both are relatively stated in equation (7) and (8). The result of relative value is showed in Table 16; it is in average value. The most proper plants planted in provinces EJ, SS, CK, EK, B, and WJ are respectively pepper, cabbage, spinach, pepper, spinach and garlic (with 0.67), and pepper.

Table 16: Relative Value of Decision

	Spinach	Tomato	Shallot	Garlic	Cabbage	Pepper
EJ	0.83	0.56	0.29	0.47	0.62	**1.00**
SS	0.05	0.43	0.66	0.40	**1.00**	0.57
CK	**1.00**	0.39	0.17	0.72	0.19	0.52
EK	0.63	0.19	0.32	0.53	0.50	**1.00**
B	0.67	0.41	0.33	**0.67**	0.17	0.60
WJ	0.63	0.23	0.36	0.26	0.38	**1.00**

$$RV_{Max} = Value_{Current} / Value_{Maximum} \quad (7)$$

$$RV_{Min} = Value_{Minimum} / Value_{Current} \quad (8)$$

3.6 Model Dashboard

The Figure 10 is the main view of the website. Consists of page navigation menu lines, namely "Home" to switch to the main page, "Crops" to move to the page that displays crop data in the system database, "Regions" to move to the page that displays the area data in the system database. On the right hand side, there is a "?" Button or help, which will display a website usage guide for users, and a "Message" button, which will display a contact page so that the user can provide feedback on system experience. In the middle, a Region selection menu is displayed which lists the regions that can be selected by the user, after selecting an area, the location of the area will appear on the map.

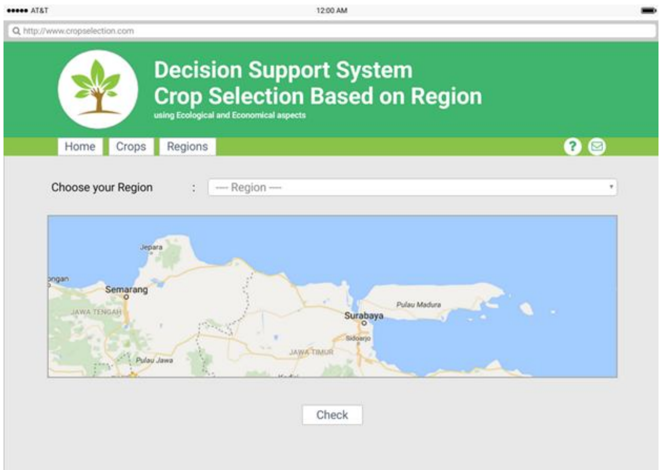

Figure 10: The Main Page of Model

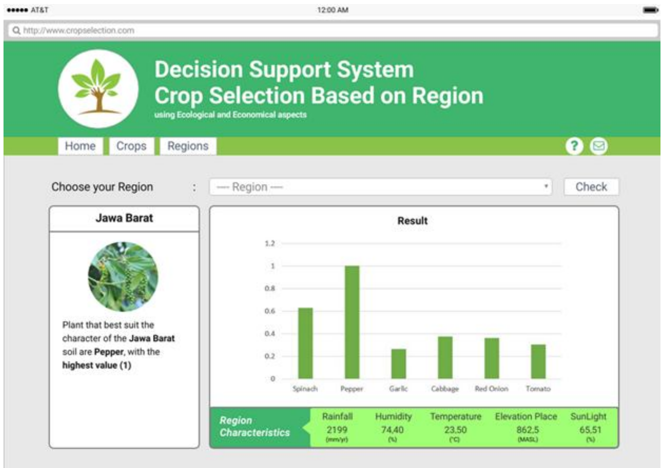

Figure 11: The Result Page of Model

Finally there is the "Check" button to execute the system, so that it can display plants that are suitable for planting. On the initial page of the website, the user is asked to select the desired area in the "Choose your Region" menu, then after the user selects the desired area, the selected location will appear in the map view. To see the results of the selection of plants that match the area, the user needs to press the "Check" button at the bottom of the screen. After that the system will display the results page, as below. On the results page (Figure 11), two columns are displayed containing explanations in the form of selected plant sentences in the left column and detailed characteristics of the area and the final crop value on the right.

4. CONCLUSION AND FURTHER WORKS

The model based on main method fuzzy logic and combined with Euclidean calculation was developed. Via using ecological and economic parameters, and six provinces in Indonesia (as a region research object), the model finally is able to propose the most proper plants being planted in one region.

The newest real data operated could make the model more prefect. And also, other optimization method use in developing the model, is able to enrich the constructed model.

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