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Honey Yield Prediction Using Tsukamoto Fuzzy Inference System

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Abstract— **Honey is a natural product of bee. Since ancient times, honey has been known by humans as a source of natural food and also for traditional medicine. There are so many beneficial of honey, make people trying to do honeybee cultivate as a business solution to increase their income. However, to cultivate honey bees is not easy. Special knowledge is required on honey bee cultivation and capital is fairly large. In order for beekeepers not to lose from honey sales business, beekeepers should be able to estimate the honey yield accurately. Predicted yield of honey is used as a material consideration and help determine the decision in honey bee cultivation. This study provides a solution for prediction of honey yield type Apis Cerana with the main food of Calliandra flowers accurately. The method used in this research is Tsukamoto's fuzzy inference system (FIS) method. There are 3 input fuzzy used in this study, namely : Rainfall, number of box, and number of flower trees. The three fuzzy inputs are the determinants of the honey yield. The representation model used in the research is Trapezoid with fuzzy rules of 125 rules. While the test data in this research are rainfall and honey yield data for 21 years. The results of this study showed that the prediction of honey yield using FIS Tsukamoto closed the real honey yield with RMSE value of 9.44933860119277.**

Keywords— prediction, Honey yield, Apis Cerana, beekeeping, beekeeper, Tsukamoto Fuzzy Inference System

I. Introduction

In the Statistics Book of the Ministry of Environment and Forests in 2015 it is written that the forest area of Indonesia reaches 96,490.8 million ha and non-forested areas of 91,427.5 million ha [1]. Forest area data is derived from the interpretation of Landsat OLI satellite imagery in 2013. This proves Indonesia is rich in flora and fauna. Indonesia has about 25,000 species of flowering plants [2] which make Indonesia a comfortable home for insects, especially honeybees. The life of a honeybee insects provides many benefits to humans. One of the benefits of honeybees is as a natural pollinator in the process of pollination of fruit crops, vegetables and grain crops [2][3]. Other benefits are derived from the products produced by honey bees.

Honey is a natural product of honeybees, other than the Wax, Pollen, propollis and royal jelly. Honey is a food that contains excellent energy for humans. It is because, honey contains simple sugars that can be directly utilized by the human body[2]. In ancient times, honey was used as a foodstuff as well as traditional medicine[4]. In the medical field, honey is used as an inhibitor of the development of 60 species of bacteria, some fungi and viruses that harm the human body [4]. Honey can be used as a food booster of human memory [5], a cure for breast cancer patients [6] or anti-cancer [7] and wound healers [8]. There are so many beneficial of honey, make people trying to cultivate honey bees, as business solutions to increase their income [9]. However, to do the cultivation of honey bees is not easy. Special knowledge is required of honey bee cultivation [10] and substantial capital for the purchase of bees, maintenance and care [11]. In order beekeepers not to lose because they have invested big capital, beekeepers should be able to estimate the yield of honey accurately.

Predicted yield of honey is used as a material to consider and help determine honey bee cultivation. Prediction of honey yield is needed not just for the beginner. Even professional beekeepers need it, especially in particular months that require them to move bees due to reduced sources of food. As far as researchers know, there is no study that specifically discusses the prediction of honey yield. And based on interviews with local beekeepers P4S, Village Giritengah, District Borobudur, it's rarely beekeepers that predict the yield of honey. Generally, local beekeepers predict the yield only by observing the season when the prediction is conducted. Frequently beekeepers experience losses from the sale of honey, This is due to the prediction of beekeepers is less accurate [13].

That is what underlies this research proposed. This study provides a solution for accurate prediction of honey yields

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using the Tsukamoto System Fuzzy Inference method. The object of the research is honey bee type Apis Cerana with main source of food of Calliandra flower tree. There are 3 Input fuzzy used in the study that rainfall [12], number of box/stup and number of flower trees [13]. Fuzzy rules of research as many as 125 rules and representation model used is Trapezoid. For measurement of system accuracy using RMSE method. Test data from this research are rainfall, number of box and number of flower trees for 21 years.

II. LITERATURE REVIEW

There are several studies that have been done previously that serve as a reference in this study.

Wahyuni(2016), researchers mentions, in the agricultural sector is highly dependent on climate, in this case is rainfall. Therefore, rainfall prediction is needed for farmers' agricultural commodities are not disturbed because of climate. The study was conducted in Tengger East Java area using Tsukamoto's fuzzy inference method[14].

Perangin-angin (2015), researchers apply fuzzy inference system Tsukamoto for the determination of reduction tuition. The fuzzy variables used as inputs in the research are economic fuzzy variables and grade point index[15].

Ramlan(2016), Fuzzy inference system Tsukamoto implemented in the manufacturing sector. In his research the case raised is the optimization of production planning. The fuzzy variables in the research are customer demand, production and inventory quantity with nine rules [16].

Bon (2016), researchers discussed about the implementation of Fuzzy Inference Tsukamoto System for decision making in production planning of crude palm oil company (CPO). The fuzzy variables used in this research are demand data, inventory data and production data in 2014. The result of this research is the firm value of result from processing of Center of Gravity method[17].

III. MATERIAL AND METHOD

A. Problem Formulation

Table 1 below contains field observation data which will be used as test data in this research. For rainfall data obtained from Semarang Climatology Station. While for the number of stup, the number of flower tress and honey yield per year is obtained from local Apis Cerana beekeepers P4S Lebah Madu Giritengah, Borobudur, Magelang, Central Java.

TABLE I. RESEARCH TEST DATA

Number of Data	Year	Rainfall	Number of Stup	Number of flower Trees
1	1996	2848	40	1500
2	1997	1389	67	1673
3	1998	3297	70	1920
4	1999	4063	100	1665
5	2000	2713	125	1550
6	2001	2533	160	1803
7	2002	2881	250	1815
8	2003	2827	280	1789
9	2004	2763	440	1922
10	2005	2532	900	1902
11	2006	2325	1150	1862
12	2007	2472	1200	2131
13	2008	2562	1300	2307
14	2009	3142	1300	2212
15	2010	3104	1300	1909
16	2011	1805	1200	1760
17	2012	1700	300	1793
18	2013	2407	150	1813
19	2014	2035	300	1823
20	2015	1979	329	1934
21	2016	3268	280	1945

Once the fuzzy variable is specified, next is to determine the range of values for the fuzzy set domain of each fuzzy variable. For fuzzy variable data and fuzzy set domain in this research can be seen in table 2 below.

TABLE II. RANGE OF FUZZY SET DOMAIN

Input variables	Fuzzy Sets	Range	Ref
Rainfall	Low	0-1771	[19]
	Medium	1389-2535	
	Rather High	1886-3299	
	High	2677-4088	
	Very High	≥3438	
Number of Stup	Very Few	0-220	[13]
	Few	45-617	
	Medium	279-912	
	Many	754.9-1199	
	Too Many	≥1042	
Number of Tree	Very Few	0-1600	[13]
	Few	1510-1847	
	Medium	1650-2076	
	Many	1893-2319	
	So Many	>2118	

And for the honey yield category is divided into 3, namely: little, medium and many. For the range of values from predicted results is shown in table 3 below.

TABLE III. RANGE OF OUTPUT

Fuzzy Sets	Range
Few	0-2666
Medium	2667-7800
Many	>7800

B. Fuzzyfication

Fuzzyfication is a part where the calculation of the Crisp value or the value of the input into the degree of membership [14][20][21]. In this study, the representation model used is a trapezoidal representation, as shown in Figure 1.

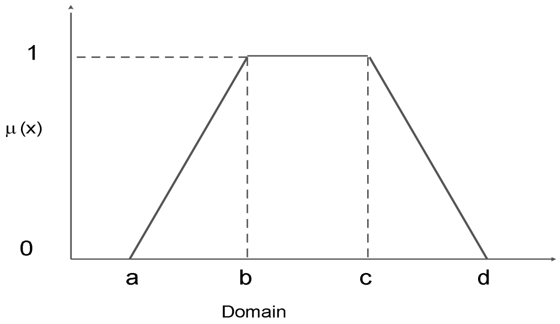

Fig. 1. Representation Trapezoid Of System

And to calculate the membership function of the fuzzy input is shown in equation 1.

$$\mu\,[x] = \begin{cases} 0; & x \le a\ OR\ x \ge d \\ (x-a)/(b-a) & a \le x \le b \\ 1 & b \le x \le c \\ (d-x)/(d-c) & x \ge d \end{cases} \quad (1)$$

The membership function of the fuzzy variable of rainfall is shown in figure 2.

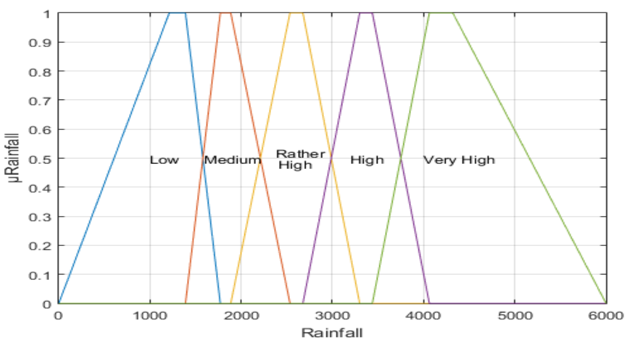

Fig. 2. The Membership function of Rainfall

Table 4 below shows position of point a, b, c, and d that represents rainfall fuzzy sets.

TABLE IV. TABLE OF RAINFALL TRAPEZOID REPRESENTATION PARAMETER

Fuzzy Sets	a	b	c	d
Low	0	1212	1389	1771
Medium	1389	1771	1886	2535
Rather High	1886	2535	2674.2	3299
High	2677	3299	3438	4088
Very High	3438	4063	4320	6000

The Membership function of the fuzzy number of stup variable is shown in Figure 3.

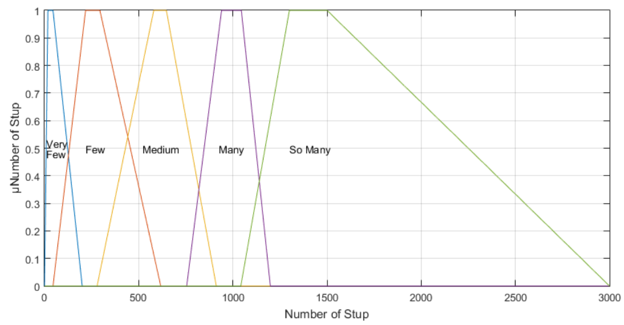

Fig. 3. The Membership function of Number Stup/Box

Table 5 below shows position of point a, b, c, and d that represents number of box fuzzy sets.

TABLE V. TABLE OF NUMBER OF BOX TRAPEZOID REPRESENTATION PARAMETER

Fuzzy Sets	a	b	c	d
Very Few	0	18	45	200
Few	45	218	294	617
Medium	279	580	647	912
Many	754.9	940	1045	1199
So Many	1042.1	1300.2	1500	3000

The Membership function of the fuzzy number of tree variable is shown in Figure 4.

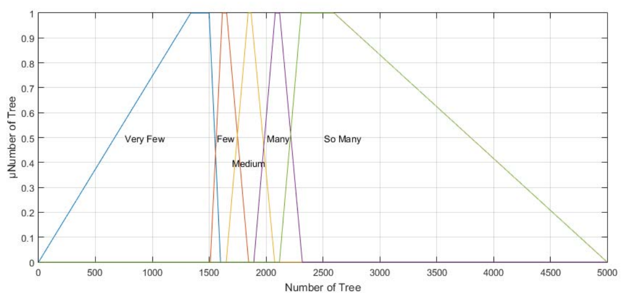

Fig. 4. The Membership function of Flower Trees

Table 6 below shows position of point a, b, c, and d that represents number of flower tree fuzzy sets.

TABLE VI. TABLE OF NUMBER OF TREE TRAPEZOID REPRESENTATION PARAMETER

Fuzzy Sets	a	b	c	d
Very Few	0	1339	1500	1600
Few	1510.1	1616	1654	1847
Medium	1650	1843	1869	2076
Many	1893	2081	2120	2319
So Many	2118.3	2309	2598	5000

Table 4 below shows position of point a, b, c, and d that represents output fuzzy sets.

TABLE VII. TABLE OF OUTPUT TRAPEZOID REPRESENTATION PARAMETER

Fuzzy Sets	a	b	c	d
Few	1510.1	1616	1654	1847
Medium	1650	1843	1869	2076
Many	1893	2081	2120	2319

After determining the position of points a, b, c, and d for each set fuzzy, then the calculation of degree of membership test data research was conducted. By looking at the range of each fuzzy set, the position of the input value will be known. Calculation of membership degree of fuzzy input value, done by using equation formula 1.

The results gained from the calculation of the degree of membership test data research can be more than 1. This is because the calculated fuzzy input data is worth meeting two or more fuzzy sets. The result of the calculation of degree of membership of test research data is presented in table 8 below.

TABLE VIII. TABLE OF RESEARCH DATA MEMBERSHIP DEGREE OF CALCULATION RESULT

Year	µ[x] Rainfall	µ[x] Number of Box	µ[x] Number of Tress
1996	0.721830985915493 and 0.27491961414791	1	1
1997	1	0.85806451612903 and 0.127167630057803	0.901554404145078 and 0.119170984455959
….	………	……	…..
2015	0.856702619414484 and 0.143297380585516	0.891640866873065 and 0.166112956810631	0.685990338164251 and 0.218085106382979
2016	0.0496158770806658 and 0.95016077170418	1	0.632850241545894 and 0.276595744680851

C. Fuzzy Inference System (FIS)

Fuzzy Inference system is a system functioned to perform calculations based on fuzzy set theory concepts, fuzzy rules, and the concept of fuzzy logic [20][21]. In FIS Tsukamoto method of inference system, every consequence of the rule is "if-then". Each consequence must be represented to a fuzzy set with a monotonous membership function[20]. The rule base in this research will be shown using 3D fuzzy surface. The result of 3D fuzzy surface rule surface can be seen in figures of 5th, 6th, and 7th.

Figure 5 is a figure of the fuzzy surface rule of Number of Box and Rainfall to the predicted yield of honey.

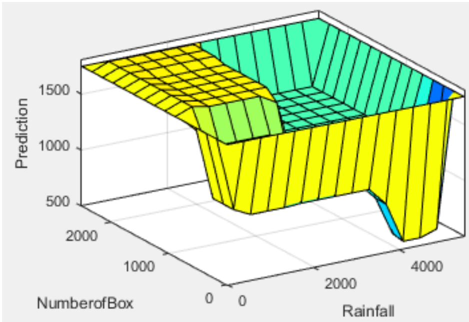

Fig. 5. The Surface Number of Box and Rainfall

Figure 6 is a figure of the 3D fuzzy surface rule of Number of Tree and Rainfall to the predicted yield of honey.

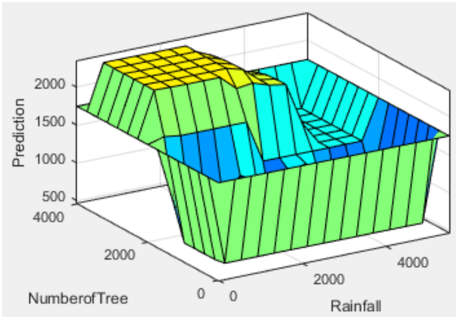

Fig. 6. The Surface Number of Tree and Rainfall

Figure 7 is a picture of the fuzzy surface rule of Number of Box and Number of Box to the predicted yield of honey.

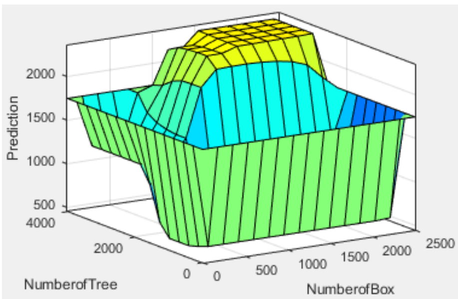

Fig. 7. The Surface Number of Tree and Rainfall

From the rule that has been determined, then the system testing will be conducted. The function of the fuzzy rule implication chosen is the MIN function. The MIN function is a process of selecting the smallest degree of membership or antecedent of a fuzzy rule. The selected antecedents (α-predicate) will be operated on fuzzy rules.

Testing the system using the test data in 1996 as the example. Rule base that meet the test data in 1996 is the 51st and 76th rule. The consequence or Output Rules 51 and 76 are low. The difference is that rule 51 lies between the points c and d, whereas the 76th rule lies between point a and b of the low output trapezoid representation. Using the equation formula (1), calculation of the value of x is conducted. For the next, the value of x is called z. The result of the operation of the test data rule of 1996 is shown in Table 9.

TABLE IX. THE OPERATION OF FUZZY RULE OF 1996 DATA TEST

Rule	Degree of Mambership			α-predicate	Z_i values
	μ[x] Rainfall	*μ[x] Number of Box*	*μ[x] Number of Tress*		
51	0.7218309 85915493	1	1	0.7218309 85915493	797.90140 8450705
76	0.2749196 1414791	1	1	0.2749196 1414791	21.718649 5176849

D. Defuzzyfication

Defuzzyfication is a value obtained from fuzzy rule compositions that are converted to crisp values [20][21]. In this research the defuzzyfication method used is center avarege defuzzyfier method, as shown in equation (2) below.

$$Z = \frac{\sum_{i=1}^{p} \mu(x)_i z_i}{\sum_{i=1}^{p} \mu(x)_i} \quad (2)$$

By using equation formula 2, defuzzyfication process is conducted from data test of the research. The result of defuzzyfication process from this research is shown in table 10 below.

TABLE X. DEFUZZIFICATION RESULT TEST DATA OF RESEARCH

Year	α-predicate	Total Z	Prediction
1996	0.996750600063403	581.920843070548	583.8
1997	1.22357411509875	621.354827373757	507.8
1998	1.05366132827013	174.860937045223	166.0
1999	1.23390539535948	233.264368521172	189.0
2000	1.93135104391322	724.449596567555	375.1
2001	1.39108960613935	1209.17322071891	869.2
2002	1.16642341093191	1217.03502714824	1043.4
2003	1.57569011613101	1435.37714522339	911.0
2004	1.80617297211174	3196.36426331701	1769.7
2005	0.940828957026426	3761.64106219784	3998.2
2006	1.37799338415313	6395.67764804119	4641.3
2007	0.908641046039409	4703.89907187945	5176.9
2008	1.04981383055814	8193.69293812787	7804.9
2009	1.53159692816515	9461.67284974777	6177.7
2010	0.909994800959333	2636.97877977414	2399.6
2011	0.741510844765932	3677.89631028374	2727.2
2012	0.83164581037842	1503.16394840151	1250.1
2013	0.493430632206344	1134.6843361691	559.9
2014	0.606990680067605	1955.83896835933	1187.2
2015	1.80949088051056	3855.16304398359	2130.5
2016	0.950608927934573	740.051959672337	703.5

E. System Accuracy

To measure the accuracy of the system in this study using the Root Mean Squared Error (RMSE) formula, as shown in equation 3 below.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(yi' - yi)^2} \quad (3)$$

RMSE = Root Mean Squared Error.
y' = Prediction Data
y = Actual Data
n = Number of Data

IV. RESULT AND DISCUSSION

The test system is done on 21 test data consisting of rainfall data and honey yield data from 1996 until 2016. The predicted results of the Tsukamoto method are obtained from the defuzzyfication process per year of yield. Then the result of the yield prediction is compared with the actual result to get the RMSE value which is the measure of the accuracy of the method proposed. Comparison of actual yield results and system predictions shown in table 11 below.

TABLE XI. CALCULATION OF SYSTEM ACCURACY

Tahun	Honey Yield		RMSE
	Actual	*Prediction*	
1996	583.7	583.8	9.449338601 19277
1997	506	507.8	
1998	166.1	166.0	
1999	186.7	189.0	
2000	375	375.1	
2001	873.8	869.2	
2002	1043.9	1043.4	
2003	912.3	911.0	
2004	1769.7	1769.7	
2005	3998	3998.2	
2006	4641	4641.3	

Tahun	**Honey Yield**		**RMSE**
	Actual	***Prediction***	
2007	5178.2	5176.9	
2008	7800	7804.9	
2009	6173.3	6177.7	
2010	2397	2399.6	
2011	2726.4	2727.2	
2012	1249	1250.1	
2013	561.8	559.9	
2014	1187	1187.2	
2015	2130.2	2130.5	
2016	703.8	703.5	

From the data shown in Table 7 above it, proves that the rainfall, the number of box/stup, and the number of flowering trees have greatly affected the yield of honey. By considering those three determinants of the honey yield, the results obtained will be optimal.

Another important thing that is shown in Table 7 above is that the most honey yield production took place in 1996, one box produced about 14.5925 kg. One year after that in 1997, the yield of honey decreased dramatically. In 1997, honey yield decreased due to very low rainfall. Then the lowest yield production occurred in 1999, that year the production of honey yield of 1.84385 kg per box. In 1999, rainfall was very high with rain intensity of 4063 mm. The difference between predicted results and the largest actual results occurred in 2008, with a value of 4.9. Then the difference between the predicted results and the smallest actual results occurred in 2004, with a value of 0. In general, the prediction of honey yield using FIS Tsukamoto close to the real results with RMSE value of 9.44933860119277.

V. Conclusion

Honey bee cultivation is one of the business solutions. In order beekeepers not to lose, beekeepers should be able to accurately predict the yield of honey. This study provides an accurate prediction of honey yields. The result of the research shows that the honey yield prediction result using FIS Tsukamoto method closed the actual result, with RMSE value of 9.44933860119277. This proves that the Tsukamoto FIS method can be used to predict the Apis Cerana honey yield.

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