Sugeno–based Fuzzy Logic Evaluation on the Effect of Weather in Coconut Scale Insect Infestation

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ABSTRACT---The purpose of this study is to evaluate the significant influence of weather in Coconut Scale Insect (CSI) Infestation happened in Batangas using the Fuzzy logic approach. The CSI and weather historical data covering the years of 2012-2014 were utilized in the study. The weather parameters used are the temperature, relative humidity, and wind speed. Fuzzy logic applying the Sugeno fuzzy inference system (FIS) in Matlab was used to simulate the effect of each weather parameters in the infestation. The developed FIS was comprised of the application of triangular membership function, formulation of 27 If-Then rules, and the center of gravity for defuzzification process. The developed system was evaluated and tested by generating 100 data samples.

Index Terms - Coconut Scale Insect, weather parameters, fuzzy logic, Sugeno inference system

I. INTRODUCTION

The coconut tree – often referred to by many Filipinos as the tree of life for its many uses such as shelter, food, and a curing balm – is fighting for its own life, and along with it, the lives of thousands of Filipinos whose livelihood depends on it [1]. In 2011, a devastating pest called "Cocolisap" infested the estimated 2.6 million of trees in CALABARZON (Cavite, Laguna, Batangas, Rizal, and Quezon) [2]. The national government in 2014, declared a cocolisap outbreak in Region IV-A after this destructive pest almost wiped out the entire coconut plantation in the region.

The outbreak was first brought to the attention of the Philippine Coconut Authority and the Department of Agriculture in 2010 when the first signs of infestation by coconut scale insects or "Cocolisap" appeared [3]. Batangas specifically Tanauan has been reported to be the most severely hit by the insect pest [4]. This destructive species has been identified as Aspiditiotusrigidus that sucks moisture from the coconut leaves, palm and fruit [5].

Based on the study conducted by the Philippine Coconut Authority (PCA) and Department of Agriculture (DA) – CALABARZON, weather is the main influencing factor in the enormous growth of the pest. The pest spread to other areas of the country due to temperature, relative humidity, wind speed and planting density [6]. Numerous studies were conducted by several crop experts to validate these findings. For such reason, the proponent intended to help such government institutions by developing a system that would confirm the assumptions that weather is the main influencing factor in the infestation.

The study considered the temperature, relative humidity and wind speed as the parameters of the system. The system was developed using Takagi-Sugeno fuzzy logic in Matlab Fuzzy logic toolbox. The designed system was based on the combination of the knowledge and expertise of different experts in crop science and agriculture from PCA and private sectors.

Fuzzy Logic is a method to solve problems in expert systems which can be viewed as an extension of the classic set theory that deals with membership of the elements and the inferences that can be arrived [7]. The idea of fuzzy logic was invented by Professor L. A. Zadeh of the University of California at Berkeley in 1965 [8]. The richness of FL is that there are enormous number of possibilities that lead to lots of different mapping [9]. The Fuzzy Inference System (FIS) contains the knowledge and experience of an expert, in the design of a system that controls a process whose input-output relations are defined by a set of fuzzy control rules, e.g., IF-THEN rules [10]. The Sugeno Fuzzy Inference System was chosen in this study because it is computationally effective and works well with optimization and adaptive techniques. The technique was applied to assess the effect of weather on the massive coconut scale insect infestation in Batangas.

A. Statement of the Problem

This study aimed to evaluate the significant influence of weather in coconut scale insect infestation.

Specifically, this study sought to answer the following questions:

1. How does the Sugeno style fuzzy logic system can be applied to evaluate the growth of coconut scale insect caused by the following weather parameters?
    a. relative humidity
    b. temperature
    c. wind speed

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2. What fuzzy rules can be formulated to identify the most favorable weather condition for coconut scale insect infestation?
3. How may the developed system be tested and evaluated?

B. *Objectives of the Study*

The primary objective of the study is to develop a system that will evaluate the significant influence of weather in coconut scale insect infestation.

Specifically, the study aims to;

1. apply the Sugeno-style fuzzy logic system to evaluate the growth of coconut scale insect caused by of the following weather parameters;
   a. relative humidity
   b. temperature
   c. wind speed
2. formulate fuzzy rules to identify themost favorable weather condition for the coconut scale insect infestation; and
3. generate 100 data samples to test and evaluate the performance of the developed system .

II. METHODOLOGY

A. *The Study Area*

The first sight of coconut insect infestation according to the PCA was in Barangay Balele, Tanauan, Batangas in March 2010. For such reason, the province was selected in the study because of its initial infestation of 15,131 coconut trees which gradually reached to 1,225,019 coconut trees in 2014. In the report presented by Manohar and Velasco in the CALABARZON region, Batangas has the highest infested trees of 25.64% of 4,777,764 total coconut trees. In 713 barangays of the province, 49% or 344 barangays were affected . Figure 1 shows the CSI pest infestation level in the province of Batangas.

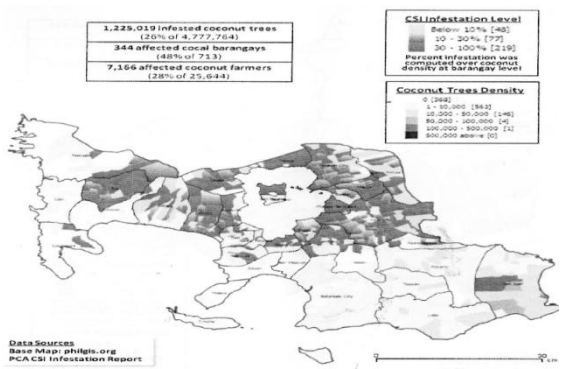

Fig. 1. CSI Pest Infestation in Batangas

B. *Data of Cocolisap Infestation in Batangas*

PCA Region IV-A in Lucena provided the cocolisap infestation data used in this study. The monitoring of the infested trees were done during every 3 months of the year.

Table I shows the monthly infestation data of the province of Batangas covering the years of 2012- 2014.

Table I.
Number of Coconut Infested Trees in Batangas
(Source: (Philippine Coconut Authority, 2016)

MONTH	2012	2013	2014
Jan- Mar	15,131	670,123	25,783
Apr-Jun	44,574	806,485	991,636
Jul-Sep	491,951	819,445	1,005,967
Oct- Dec	506,703	770,536	1,225,019

Table II shows the historical weather data of the province of Batangas gathered from weatherdataphils.com. The three-year historical data of weather was collected covering the periods of 2012- 2014.

Table II.
Batangas Weather Data

Month	2012			2013			2014		
	TEMP	WS	HUM	TEMP	WS	HUM	TEMP	WS	HUM
JAN	31	22	68	30	22	60	30	22	56
FEB	32	22	68	32	49	60	31	26	58
MAR	33	25	64	33	22	59	32	26	79
APR	34	20	58	34	22	56	34	18	76
MAY	34	22	70	35	22	64	35	18	84
JUN	33	32	74	33	18	74	34	14	76
JUL	33	26	80	33	22	74	34	27	80
AUG	31	40	80	32	29	79	31	29	83
SEPT	33	22	80	33	40	80	32	26	80
OCT	33	22	73	30	43	75	32	21	77
NOV	32	22	64	32	36	73	32	21	83
DEC	32	18	66	32	22	71	31	26	76

Legend : TEMP - Temperature, WS - Wind Speed, HUM - Relative Humidity

C. *Sugeno Fuzzy Inference System Method*

The Takagi-Sugeno Fuzzy logic systems are based on local linear function, and the global nonlinear is implemented by blending the subsystems' models. According to Cavallaro (2015), the T-S style fuzzy rule is: IF x is A AND y is B THEN z is f (x, y) where x, y, and z are linguistic variables, A and B are fuzzy sets on universe of discourses X and Y and f (x, y) is a mathematical function. Sugeno-type FIS uses a weighted average to compute the crisp output.

Takagi Sugeno Fuzzy Inference System applied in the study composed of three blocks. First, fuzzification which translates inputs into a linguistic value, inference engine which evaluates the degree of membership and assigns fuzzy rules, and finally the defuzzification which transfers linguistic values into output.

Figure 2 shows the architecture of the designed system. The concept is to provide an output based on the weather information which will serve as the input data. The input parameters for fuzzification are the temperature, relative humidity, and the wind speed. The output parameter is the number of infested trees which is based on the influence of the weather as inputs.

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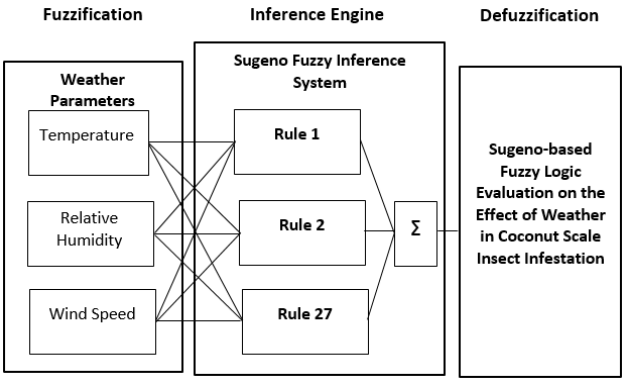

Fig. 2. Architecture of the System

III. RESULTS

A. The Sugeno FIS

The designed Sugeno FIS was developed by assigning linguistic variables and their classification ranges which were set through the supervision of PCA. The chosen membership function applied in this study is the triangular membership function. Table III shows the linguistic variables and the assigned ranges of input and output parameters utilized in the study.

Table III.
Parameters and Classification Ranges

Parameters	Classification Ranges		
A. Input	**Maximum**	**Average**	**Minimum**
Temperature	30-45	20-29	1-19
Relative Humidity	75-95	65-74	5-64
Wind speed	25-85	11-24	1-10
B. Output	**Severe**	**Moderate**	**Low**
No. of Inf. Trees	5,000up	1,000-4,999	1-999

Figure 3 shows the information about a fuzzy inference system with the names of each input variable on the left and the output variable on the right.

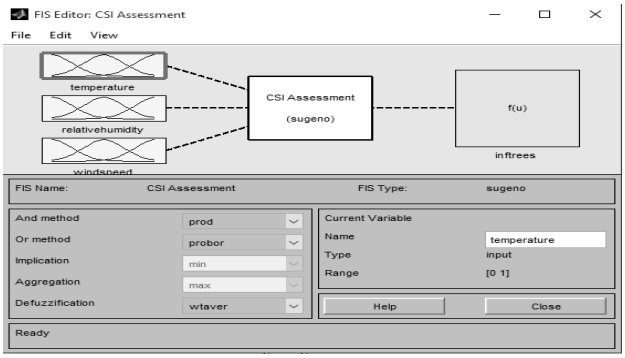

Fig.3.The FIS Editor

Figure 4 shows the temperature triangular membership functions of the designed fuzzy inference system. The temperature membership functions are interpreted as the minimum, average and maximum

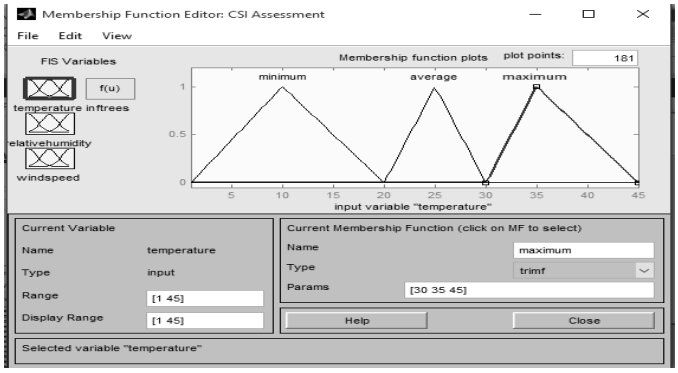

Fig. 4. The Membership Function Editor

Figure 5 shows the generated rules for the designed fuzzy logic engine.

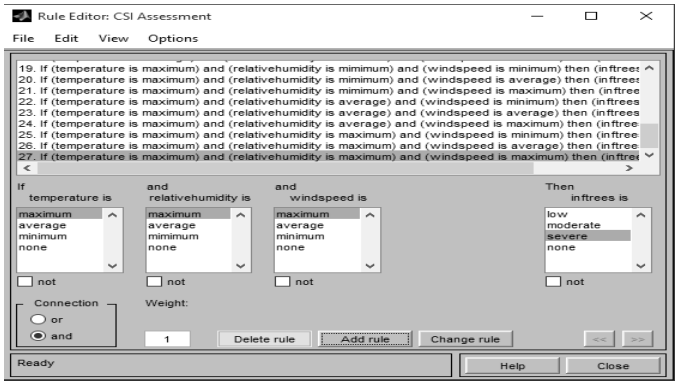

Fig. 5. The Rule Editor

Figure 6 shows the Rule Viewer of the designed fuzzy logic system. The defuzzified output value is shown by the thick line passing through the aggregate fuzzy set.

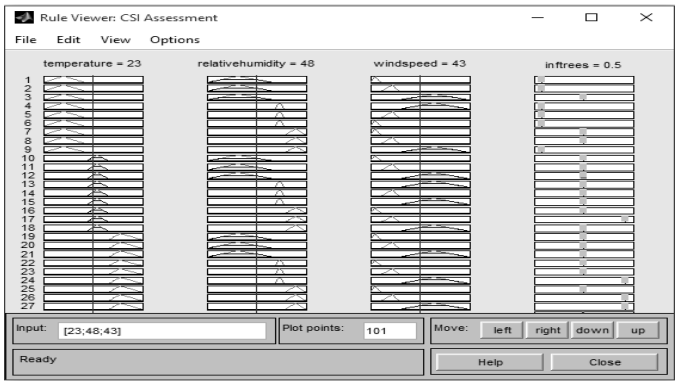

Fig. 6. The Rule Viewer

B. The Formulated Fuzzy Rules

Fuzzy rules are collection of linguistic statements that describe how the FIS should make a decision regarding classifying an input or controlling an output. Table IV shows the examples of the 27 formulated rules used in the developed uzzy logic system.

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Table IV.
The Formulated Fuzzy Rules

No.	Rules
1	If temperature is minimum, and relative humidity is minimum, and wind speed is minimum, then no. of inf trees is low
2	If temperature is minimum, and relative humidity is minimum, and wind speed is average, then no. of inf trees is low
3	If temperature is minimum, and relative humidity is minimum, and wind speed is maximum, then no. of inf trees is moderate
Rn	If temperature is ..., and relative humidity is ..., and wind speed is ..., then no. of inf trees is ...
Rn	If temperature is ..., and relative humidity is ..., and wind speed is ..., then no. of inf trees is ...
27	If temperature is maximum, and relative humidity is maximum, and wind speed is maximum, then no. of inf trees is severe

C. System Testing

The system testing applied in this study is based on the year 2014 history of CSIinfestation and the weather data of the province of Batangas. The tested data were the 2014 average weather and the 2014 recorded infestation. Table V shows the comparison of the data generated from the developed FIS and the computed actual values based on the assigned ranges by the PCA.

Table V.
The Comparison ofData

TRIALS	PARAMETERS	FUZZY LOGIC		COMPUTED VALUES (ACTUAL)		
		DATA VALUE	CRISP OUTPUT (MATLAB)	ACTUAL VALUE	NO. OF INF. TREES	Num. Equiv.
1	Temperature	1	1	15	264	1
	Relative Humidity	1		54		
	Wind Speed	1		5		
2	Temperature	1	1	12	302	1
	Relative Humidity	2		66		
	Wind Speed	1		6		
3	Temperature	2	2	26	1805	2
	Relative Humidity	2		66		
	Wind Speed	2		23		
4	Temperature	3	2	30	1730	2
	Relative Humidity	1		62		
	Wind Speed	1		10		
5	Temperature	3	3	32	2953	3
	Relative Humidity	2		70		
	Wind Speed	3		45		
6	Temperature	3	3	37	3386	3
	Relative Humidity	3		90		
	Wind Speed	3		45		

IV. CONCLUSION

Based on the results of the study, it yielded the following conclusions: The used of the triangular membership functions,the formulation of 27-fuzzy rules in AND operation and the center of gravity defuzzification are the processes involved inthe application of Sugeno FIS in evaluating the effect of weather in CSI infestation happened in Batangas. The 27 If-Then rules were produced based on the classification ranges set by crop experts .The 100 data samples generated from the developed system proves that the temperature has the biggest impact in the infestation followed by the wind speed and the humidity. The developed system verifies the findings of the study of PCA that weather is the foremost reason of the CSI infestation.

V. RECOMMENDATION

The system can be more effective if it would be designed together with the traditional forecasting techniques applying the statistical tool such as SPSS. The study also suggests the designing of the user interface which provide an easy access with the users. In addition, it is also recommended to consider other provinces in CALABARZON such as the provinces of Cavite, Laguna, Quezon and Rizal in evaluating the effect of weather in the infestation. At the same time, it would be a big help if other factors other than weather would be consider in the future study.

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