Development of Weather-based "Cocolisap" Infestation Forecasting System for CALABARZON using Fuzzy Logic

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Abstract

The purpose of this study is to develop a weather-based forecasting system for CALABARZON region generated from Sugeno-style fuzzy inference system in MATLAB and realized in MS Excel VBA Macro. The study evaluates the influence of temperature, relative humidity, wind speed, and the planting density in "Cocolisap" infestation to forecast the number of infested coconut trees and its degree of infestation. The Fuzzy Inference System (FIS) technique comprises of the application of triangular membership function, formulation of 81 If-Then rules, application of AND logic operators, and the weighted defuzzification process. The user interface for the designed system is programmed in MS Excel VBA Macro.

The designed system was simulated by comparing the year 2014 historical data of "Cocolisap" infestation to the generated data of the developed software. The results were evaluated and verified by the Philippine Coconut Authority (PCA) Cavite-Batangas Provincial Office, several software developers and fuzzy logic experts. On the basis of the results of this study, it was concluded that fuzzy logic concept which integrated in VBA Macro is an effective and powerful tool that can be applied in "Cocolisap" infestation forecasting.

Keywords: *Cocolisap Infestation, Forecasting system, Fuzzy Logic, Sugeno-style fuzzy inference system, triangular membership function, defuzzification*

1. Introduction

The Philippines has the world's largest agricultural area planted with coconut palms and is second to Indonesia as the world's top producer of coconut products [1]. The coconut industry is a dominant sector of the Philippine agriculture wherein 12 million hectare of farmlands, 3.1M hectares is devoted to coconut. The Philippine Coconut Authority (PCA) estimates that 25M Filipinos are directly or indirectly dependent on the industry and about sixty- eight (68) out of 79 provinces in the country are coconut areas[2].

In 2014, the country's coconut industry faced the worst problem it has encountered in many decades. A destructive scale insect infested the 60 percent of the total coconut farming areas in the country, most of which is in CALABARZON (Cavite, Laguna, Rizal, Batangas, Quezon) [3]. It is estimated that around 2.6 million of trees in CALABARZON where infested with this Coconut Scale Insect or locally known as the "Cocolisap".

The "Cocolisap" was first sighted in Balele, Tanauan, Batangas in March, 2010. Batangas specifically Tanauan has been reported to be the most severely hit by the insect pest. This destructive species has been identified as Aspiditiotus rigidus that sucks moisture on coconut leaves, the palm and the fruit itself. A. rigidus was first described as

a subspecies of A. destructor by Reyne in 1947 (with the name A. destructor rigidus) based on biological and morphological features and its status changed to A. rigidus in 1966 based on more rigorous scientific evaluation. It was a serious pest of coconut palm reported in 1947 in Sangi Island which is between Sulawesi, Indonesia and Mindanao, Philippines [4].

The Philippine Coconut Authority and Department of Agriculture (DA) – CALABARZON presumed that the infestation spread to other areas of the country due to temperature, relative humidity, wind speed and planting density [5]. For such reason, the study is intended to foresee the presence of pests' occurrence in coconut trees caused by these factors which could spur the massive growth of the pest. The forecasting system was developed from the combination of the knowledge and expertise of different experts in crop science and agriculture, researchers, traders, coconut growers, and farmers. It was developed using Takagi-Sugeno Fuzzy logic in MATLAB Fuzzy Logic Toolbox.

Fuzzy logic systems have been successfully applied to a number of scientific and engineering problems during recent years [6]. The idea of fuzzy logic was invented by Professor L. A. Zadeh of the University of California at Berkeley in 1965 [7], [8]. It is able to simultaneously handle numerical data and linguistic knowledge. 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 [9], [10].

1.1. Statement of the Problem

This study aimed to develop a weather-based forecasting system generated from the fuzzy inference technique in MATLAB and realized in MS Excel VBA Macro. Specifically, this study sought to answer the following questions:

1. What are the data that can be used to predict the severity of "Cocolisap" infestation?
2. How can the Fuzzy Inference System (FIS) process be implemented in MATLAB to forecast the number of infested coconut trees caused by temperature, relative humidity, wind speed and planting density?
3. What algorithm may be used to develop the designed fuzzy inference system in MATLAB to MS Excel VBA Macro?
4. How may the developed system be tested and evaluated in determining its capability to accurately forecast the severity of "Cocolisap" infestation?

1.2. Objectives of the Study

The primary objective of this study is to develop a weather-based forecasting system generated from fuzzy inference technique in MATLAB and realized using MS Excel VBA Macro. Specifically, the study aimed to achieve the following:

1. Determine the data that can be used to forecast the severity of "Cocolisap" infestation.
2. Implement the Fuzzy Inference System (FIS) process in MATLAB to estimate the number of infested coconut trees caused by temperature, relative humidity, wind speed and planting density.
3. Develop an algorithm that may be used to design the fuzzy inference system in MATLAB to MS Excel VBA Macro.
4. Test and evaluate the developed fuzzy system to determine its capability to accurately forecast the "Cocolisap" infestation.

2. Research Methodology

2.1. Methods and Procedures

The methods are divided into three major phases: data gathering, system development, and system evaluation.

1. Data Gathering Phase

Figure 1 shows the data gathering phase which includes the review on the different published literature, research papers, surveys, and reports. Different stakeholders were interviewed and consulted in the conceptualization of the system.

2. System Development Phase

System development is the standard process or flow of the methodology to structure all steps necessary to analyze, design, implement and test the system. Originally, the Waterfall model was proposed by Winston W. Royce in 1970 to describe a possible software engineering practice [11]. The SDLC Waterfall model served as guide in the system development phase of this study.

3. System Evaluation Phase

The last phase of the study is the evaluation of the system with the intended users and several software developers and fuzzy experts. This process was conducted to assess the quality, accuracy and reliability of the system using the ISO 9126.

2.2. Software Requirements

The system used the Fuzzy Logic Toolbox software available in MATLAB 2016 The study utilized the MATLAB 2016 to develop a fuzzy inference system in Simulink and simulate the fuzzy systems within a comprehensive model of the entire dynamic system. The fuzzy logic model in the study was realized in MS Excel VBA Macro 2016.

3. Presentation and Analysis of Research Output

3.1. The Data Used in the Developed Fuzzy Logic Program

Table 1 below shows the "Cocolisap" infestation data of CALABARZON on year 2014. These information were compared to the data gathered on year 2013. The figures presented was very significant in the development of the fuzzy program because the output of the system was based on these figures.

Table 1. Infestation Data for Year 2014

Province	AREA	Total Coconut Trees	No. of Infested Trees	Inf. Percentage
Cavite	11,204.00	1,386,625.00	216,948.00	15.65
Laguna	58,704.00	7,596,362.00	549,464.00	7.23
Batangas	29,555.00	4,777,764.00	1,225,019.00	25.64
Quezon	379,435.00	62,752,478.00	684,353.00	1.09
Total	478,898.00	76,513,229.00	2,675,784.00	3.50
Source: PCA Coconut Production Survey 2012 and CSI Infestation Report 2014				

Table 2 shows the summarized average weather information in CALABARZON. The researcher utilized the three consecutive years' weather history to completely study the substantial influence of weather in the infestation from the first year it started up to the year it became an outbreak.

Table 2. Summary of Weather Data of CALABARZON

		MONTH	TEMPERATURE C	TEMPERATURE L	TEMPERATURE B	TEMPERATURE Q	WIND SPEED C	WIND SPEED L	WIND SPEED B	WIND SPEED Q	RELATIVE HUMIDITY C	RELATIVE HUMIDITY L	RELATIVE HUMIDITY B	RELATIVE HUMIDITY Q
2012		Jan- Mar	32	31	32	32	23	19	23	23	67	64	67	67
		Apr-Jun	34	33	34	34	48	45	48	48	67	67	67	67
		Jul-Sep	32	32	32	32	30	24	29	29	83	81	81	77
		Oct- Dec	32	31	32	32	21	18	21	21	68	68	68	67
2013		Jan- Mar	32	31	32	32	29	18	31	29	60	56	60	60
		Apr-Jun	34	34	34	34	16	18	21	19	65	64	65	65
		Jul-Sep	32	32	33	33	30	21	30	30	80	80	79	79
		Oct- Dec	31	31	31	31	34	22	34	34	73	73	73	73
2014		Jan- Mar	31	31	31	30	38	19	25	21	58	64	64	77
		Apr-Jun	34	35	34	33	18	15	17	18	63	70	82	85
		Jul-Sep	32	33	32	32	25	29	27	10	77	79	90	90
		Oct- Dec	32	32	32	30	21	22	23	21	72	76	85	91

C - Cavite L - Laguna B - Batangas Q- Quezon

3.2. Description of the Fuzzy Inference Process for the Weather-based "Cocolisap" Forecasting System for CALABARZON

In this study, the input and output parameters were chosen based on the contributing factors to "Cocolisap" infestation identified by the Philippine Coconut Authority (PCA). Table 3 shows the parameters and the linguistic values used in the study.

Table 3. Linguistic Values of Parameters Used in the Study

Parameters	Linguistic Value
Temperature	Maximum, Average, Minimum
Relative Humidity	Maximum, Average, Minimum
Wind Speed	Maximum, Average, Minimum
Planting Density	Maximum, Average, Minimum
Infestation	High, Moderate , Low

Table 4 shows the inputs classification ranges which were used in developing the membership function of the fuzzy program.

Table 4. Fuzzy Inputs and Classification Ranges

Parameters	Observed Ranges	Allowable Ranges	Triangular Ranges		
			Maximum	Average	Minimum
Temperature	25-35	1-45	30-45	20-29	1-19
Relative Humidity	51-86	1-95	75-95	65-74	75-95
Wind Speed	8 -49	1-85	25-85	11-24	1-10
Planting Density	98- 160	1-200	131-200	100-130	1-99

Table 5 shows the examples of these 81 rules utilized in the developed fuzzy logic system.

Table 5. The Formulated Fuzzy Rules

No.	Rules
1	If (temperature is maximum) and (relative humidity is maximum) and (wind speed is maximum) and (planting density is maximum) then (infestation is high)
2	If (temperature is maximum) and (relative humidity is maximum) and (wind speed is maximum) and (planting density is average) then (infestation is high)
3	If (temperature is maximum) and (relative humidity is maximum) and (wind speed is maximum) and (planting density is minimum) then (infestation is high)
4	If (temperature is maximum) and (relative humidity is maximum) and (wind speed is average) and (planting density is maximum) then (infestation is high)
Rn	If ……
---	If ……
80	If (temperature is minimum) and (relative humidity is minimum) and (wind speed is minimum) and (planting density is average) then (infestation is low)
81	If (temperature is minimum) and (relative humidity is minimum) and (wind speed is minimum) and (planting density is minimum) then (infestation is low)

3.3. The Fuzzy Inference System (FIS) Developed in Fuzzy Logic Toolbox in MATLAB

Figure 1 shows the five GUI tools developed in Fuzzy Logic Toolbox in MATLAB which was designed for the weather-based "Cocolisap" infestation forecasting system for CALABARZON. The FIS model contained the FIS Editor, Membership Function Editor, Rule Editor, Rule Viewer and the Surface Viewer.

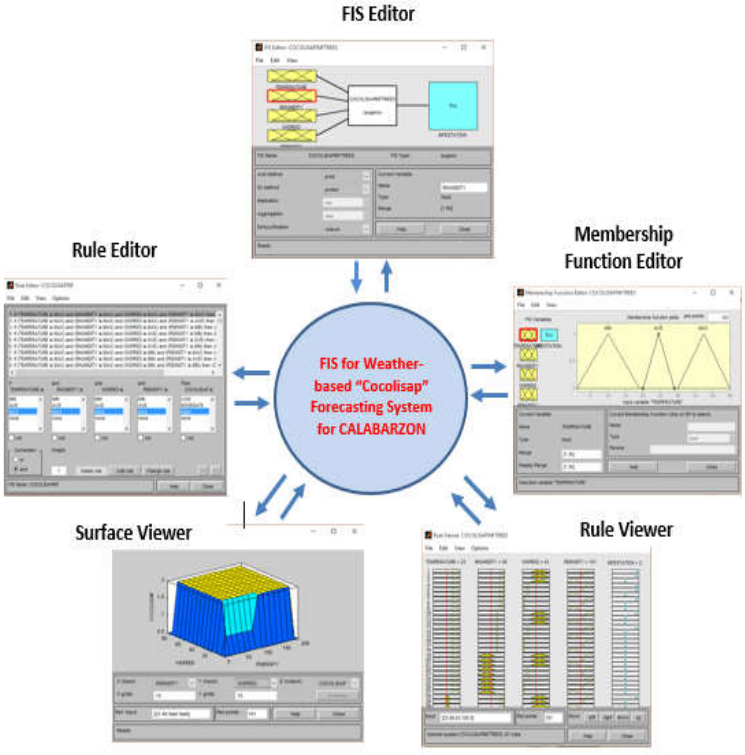

Figure 1. The Developed FIS

Figure 2 shows the designed user interface developed in MS Excel VBA Macro In order to appreciate the developed fuzzy logic model built in Fuzzy Logic Toolbox in

MATLAB, the researcher created the MS Excel VBA Macro program to be utilized by its intended users

Figure 2. The System's GUI

3.4. Results of System Testing and System Evaluation

The system testing applied in this study is based on the year 2014 history of "Cocolisap" infestation in 2014 and the weather data of the Province of Batangas. The tested data were the 2014 average weather versus the 2014 total infestation. Table 6 shows the comparison of the 2014 infestation information in the Province of Batangas and the results of the generated data from the developed program.

Table 6. Comparison of 2014 Infestation Data vs. the Generated Data

2014 Historical Data		Generated Data	
Variables	**Value**	**Variables**	**Value**
Temperature	32	Temperature	32
Relative Humidity	76	Relative Humidity	76
Wind Speed	23	Wind Speed	23
Planting Density	136	Planting Density	136
Area	29555	Area	29555
No. of Coconut Trees	4777764	No. of Coconut Trees	4777764
No. of Infested Coconut Trees	1225019	No. of Infested Coconut Trees	1714233
Degree of Infestation	26	Degree of Infestation	36

As shown in the table, there's a 10% discrepancy on the actual infestation data and the generated data. It was resulted caused by other external factors that contributes on the infestation. It was clarified by the PCA and the consulted expert in agriculture that this 10% difference in the result is an expected output because of the contributing efforts of the government to mitigate this "Cocolisap" issue.

4. Conclusions

Based on the result it yielded the following conclusions: The data that can be used to predict the severity of "Cocolisap" infestation include the 2012- 2014 weather data, and the 2013-2014 infestation data. An FIS contains information and experience of an expert in the design of a system that controls the process whose input-output relationship is defined by a set of fuzzy rules. The If-Then fuzzy rules in fuzzy logic provide simulation

in evaluating the severity of "Cocolisap" infestation caused by the temperature, relative humidity, wind speed and planting density. The graphic user interface of the system developed in MS Excel VBA Macro is an effective tool which realizes the designed fuzzy logic model. The algorithm presents a broad knowledge on how the concepts of a fuzzy model can be applied in MS Excel VBA Macro. The study determines that ISO 9126 software standard is an effective tool in determining the capability of a system. The passing result of the evaluation based on this standard proves that the developed system is an effective and powerful tool that can be applied in "Cocolisap" infestation forecasting.

5. Recommendations

Based on the findings and conclusions made, the following are the recommendation of this study. The study recommends the application of API for the automated interface of the system so that real-time weather data from PAGASA can be employed. The study suggests the application of the developed system in a higher programming languages such as Visual basic or PHP. The study proposes the consideration of other factors such as human, animals, topological location of the area in forecasting the severity of pest infestation.

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