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Original Article

Prediction of essential oil content in *C. sintoc* Leaves based on the direction of vegetation slope in Mount Ciremai National Park using ANFIS Artificial Neural Network

Previsão do conteúdo de óleo essencial em folhas de *Cinnamomum sintoc* com base na direção da encosta da vegetação no Parque Nacional Monte Ciremai usando redes neurais artificiais ANFIS

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Abstract

C. sintoc is a plant that has a high essential oil content. Essential oils have many health benefits. Mount Ciremai National Park is an area that has abundant vegetation, especially *C. sintoc*. The purpose of this study was to predict the volume of oil contained in the leaves of *C. sintoc* based on its growing location in Mount Ciremai National Park (TNGC), West Java. Sampling was carried out in two stages, namely field samples and laboratory samples. Field samples with a single plot measuring 20 x 20 meters. Extraction of laboratory samples by steam distillation method. Data analysis using ANFIS method to predict the volume of essential oil. The results showed that the volume of essential oil in the leaves was largest on the western slope (1,96 ml), northern slope (2,01 ml), eastern slope (1,55 ml) and southern slope (1,37 ml) while the essential oil yield of extract oil in the leaves is found on the western slope (0,08%), northern slope (0,07 %), eastern slope (0,06 %) and southern slope (0,04), On the western slope (1,82 ml), northern slope (1,73 ml). The ANFIS analysis results showed a prediction accuracy of 90,99% with the highest tree productivity when *C. sintoc* BL grows at an altitude of 650-700 meters above sea level, tree diameter of 42 cm, height of 12 m, growing on sand-textured land and at a humidity of 75 and at a growing temperature range of 25-270C. The value of essential oil production volume is influenced by each variable such as tree diameter, tree height, soil texture, altitude, temperature and humidity.

Keywords: ANFIS, *Cinnamomum Sintoc,* essential oil, leaf.

Resumo

Cinnamomum sintoc é uma planta que possui alto teor de óleo essencial. Os óleos essenciais podem apresentar muitos benefícios para a saúde. O Parque Nacional Monte Ciremai é uma área que possui vegetação abundante, principalmente *C. sintoc.* O objetivo deste estudo foi prever o volume de óleo contido nas folhas de *C. sintoc* com base em sua localização de crescimento no Parque Nacional Monte Ciremai (TNGC), Java Ocidental. A amostragem foi realizada em duas etapas, nomeadamente amostras de campo e amostras de laboratório. Amostras de campo foram coletadas em área com parcela única medindo 20 × 20 metros. Para a extração de amostras laboratoriais, utilizou-se o método de destilação a vapor. Análise de dados foi realizada utilizando o método ANFIS para previsão do volume de óleo essencial. Os resultados mostraram que o volume de óleo essencial nas folhas foi maior na encosta oeste (1,45 mL), sendo na encosta norte (1,37 mL), na encosta leste (1,09 mL) e na encosta sul (0,88 mL), enquanto o volume de óleo extraído nas folhas são encontradas na encosta oeste (1,45 mL), encosta norte (1,37 mL), encosta leste (1,09 mL) e encosta sul (0,88 mL). Na encosta oeste (1,82 mL), encosta norte (1,73 mL), encosta leste (1,24 mL) e encosta sul (1,22 mL). Os resultados da análise ANFIS mostraram uma precisão de previsão de 90,99%, apontando a maior produtividade de árvores quando *C. sintoc* BL cresce a uma altitude de 650-700 m acima do nível do mar, com diâmetro da árvore de 42 cm e altura de 12 m, crescendo em textura de areia terra, a uma umidade de 75% e a uma faixa de temperatura crescente de 25-27°C. O valor do volume de produção de óleo essencial é influenciado por cada variável, como diâmetro da árvore, altura da árvore, textura do solo, altitude, temperatura e umidade,

Palavras-chave: ANFIS, *Cinnamomum sintoc*, óleo essencial, folha.

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1. Introduction

C. sintoc is widely distributed in Mount Ciremai National Park (TNGC), West Java, *Cinnamon* (*Cinnamomun* sp.) is one of the multi-functional plants that can be utilized in the food and beverage industry, medicine, essential oils and oleoresins derived from the stem, branches, twigs, leaf tops and roots of the plant, This plant is widely found growing in West Java, Central Java, Malaysia and Thailand. Based on the research of Ismail et al. (2019) in West Java, precisely in Mount Ciremai National Park (TNGC), this plant lives and develops with the category of rare plants, is able to grow at an altitude of 500-1200 meters above sea level or in lowland forests and is quite tolerant of the environment with different lengths of sunlight.

This plant has a morphology with a height of up to 40 meters and a stem diameter of up to 30 cm, the bark is brownish gray and reddish on the inside, Then the leaves are oval-shaped green with a shiny surface, the leaves have a clove-like aroma when squeezed, The flowers of *C. sintoc* have a white to pale yellow color and the fruit is oval with a size of 1,8 cm x 0,8 cm (Wuu-Kuang, 2011).

Besides being a rare or endangered plant species, *C. sintoc* also produces essential oils from its roots, bark, and leaves with 30 chemical components (Ismail et al., 2019), The essential oil of *C. sintoc* found in Malaysia has the main component in the leaves, namely Safrole (23,4%) and in the bark, namely Linalool (23,8%) (Salleh et al., 2016). Meanwhile, according to research by Sumiwi et al. (2015), the bark of *C. sintoc* contains 36 chemical components with the main component being eugenol (38,38%). International research examining *C. sintoc* includes research on the antifungal activity of extracts and active fractions of the plant, Essential oils from this plant are much needed for the needs of the pharmaceutical industry, cosmetics, soap, air fresheners and the food industry. The international market demand for essential oils, namely the consumption of essential oils and their derivatives, has increased by around ten percent from year to year (Akbar, 2020). The largest *C. sintoc essential* oil producing countries are China, Vietnam and Taiwan, which are characterized by the presence of large industries and large-scale cultivation activities (Luo et al., 2005; Zhao et al., 2010; Wang and Liu, 2010),

The main problems that arise in its current development, especially in Indonesia, are: 1) there is still very limited research support in the field of *C. sintoc* ecology, especially with regard to habitat characteristics and ecological preferences, as well as habitat factors that contribute to the best or highest essential oil content both in quantity and quality; 2) the cultivation of *Cinnamomum sintoc* BL has not been carried out either on a small or large scale which has caused Indonesia not to become a producer of essential oils and products made from *C. sintoc while in the field of pharmaceutical and industrial technology has developed rapidly, especially on* essential oils produced from the leaves of this tree, *Syntoc BL* even though the pharmaceutical and industrial technology has developed rapidly, especially about essential oils produced from the leaves of this tree, including research on genetic and molecular aspects (Chang and Chu, 2011; Wang et al., 2009).

The presence of *C. sintoc* as a pioneer tree species in disturbed areas with limited environmental factors suggests that this tree species has specific preferences for habitat factors that contribute to essential oil content, As a result of secondary metabolism of a plant, essential oils produced must be controlled by certain environmental factors (Cesco et al., 2007). Barret (1981) explains, organisms that live in an environment with high stress will adapt and increase self-defense by carrying out secondary metabolism, in another sense that the higher the level of stress in the environment, the higher the biosynthetic process that produces secondary metabolites.

Based on the above factors, integration is needed to maximize the benefits of the *C. sintoc* plant, In this case, an artificial neural network is needed to predict the capacity of essential oil contained in this plant based on environmental variables and the morphology of the *C. sintoc* plant. The artificial neural network used in this research uses ANFIS as an application to perform prediction analysis.

ANFIS is an inference system based on artificial neural networks and fuzzy logic. This approach allows combining artificial intelligence (neuro) and fuzzy logic to create a prediction model that can adapt to the data. In predicting the essential oil content of c,sintoc plants, ANFIS can be used by inputting the main variables that affect the essential oil content of *C. sintoc* plants such as tree diameter, tree height, soil texture, altitude, temperature and humidity.

Based on the information above, it shows that the volume of essential oil of *C. sintoc* has a different content from one place to another, this requires research to determine and predict the content of essential oil volume in Mount Ciremai National Park (TNGC) and the factors that influence it.

2. Research Methodology

This research was conducted in Mount Ciremai National Park (TNGC), West Java, With the location determined purposively or intentionally. With the consideration that the Mount Ciremai national plant area has a variety of MDPL heights ranging from 500-1200 meters above sea level and there are 4 slopes used as sampling areas. The scope of this research includes (i) water distillation (hydrodistillation) to determine the essential oil content in C,sintoc leaves and obtain essential oil by measuring the volume of each sample, and (ii) prediction of the content of each sample based on predetermined variables using ANFIS artificial neural network, Below is a map of the distribution of *C. sintoc* plants around Mount Ciremai National Park.

2.1. Plant material

Plant material of *C. sintoc* used for research in the form of leaves taken based on plots determined from various directions of the slopes of Mount Ciremai National Park, Plant material was taken from 4 slope directions, namely north, south, west and east.

Ecological data were obtained through purposive placement of single 20 x 20 m plots in areas where *C. sintoc* grows, In each plot, vegetation and physical observations were made in the form of soil, climate (temperature, humidity and light intensity), slope and altitude (Kusmana, 1997), The establishment of observation plots was carried out along the observation pilot line with a *nested design placement* (Figure 1), The placement of sample plots in this study always pays attention to the physical aspects of the area such as altitude and slope direction by cutting the contour direction,

Leaf samples of *C. sintoc* were taken from one mature tree (diameter > 20 cm) in each plot by cutting 30 cm long leaf branches from the top at various sides (4 slope directions) and crown positions (top, middle, and bottom) to obtain a weight of 2,5 kg. Samples were then put into plastic bags and labeled with codes and clear descriptions, including coordinates, habitat type, specific site name and other attributes, The initial treatment of the samples was air drying, then three representative leaves and stems were taken from each sample to calculate the moisture content based on the ratio of the initial weight and the weight after being baked at 70° C for 2 hours. Air-drying treatment is intended to evaporate some of the water in the raw material so that the distillation process becomes easier, shorter and more uniform (Rahayoe et al., 2007), Figure 2 below shows the samples taken and air-dried.

Distillation of essential oils using a steam distillation system as much as 200 g with a process time of 3 hours per sample for two repetitions, The steam distillation procedure is carried out according to the applicable standards in the Bandung Polytechnic Laboratory, namely flowing water vapor produced by the steam generator into the simplisia container, the water vapor then carries the essential oil into the storage tube, Steam distillation is the best distillation method because it can produce high quality essential oils without mixing with water (Suryani, 2012). The essential oil obtained is then measured by weight and calculated the yield (in percent) by comparing the volume of distilled oil with the weight of air-dried material, Figure 3 below shows the distillation process carried out.

To get the results of the *C. sintoc* Leaf Essential Oil Content Prediction Model, modeling is carried out using the ANFIS method and designing several inputs and outputs that will be used in this analysis. The next step is to create the desired range of values and name each data parameter as follows: tree diameter, tree height, soil texture, temperature, humidity, and soil elevation for input and output, respectively. A hybrid learning algorithm for ANFIS was used in this study (Figure 4). A variant of the algorithm used was two input membership functions for each input. The dataset of the available system includes 31 data patterns, In addition,

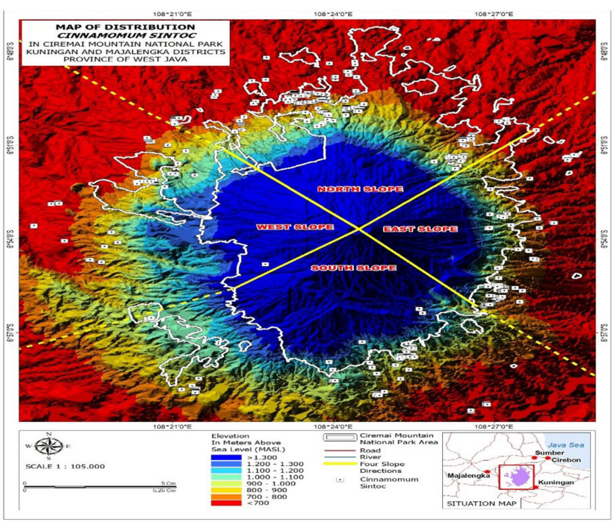

Figure 1. Distribution Map of C. sinton in Mount Ciremai National Park.

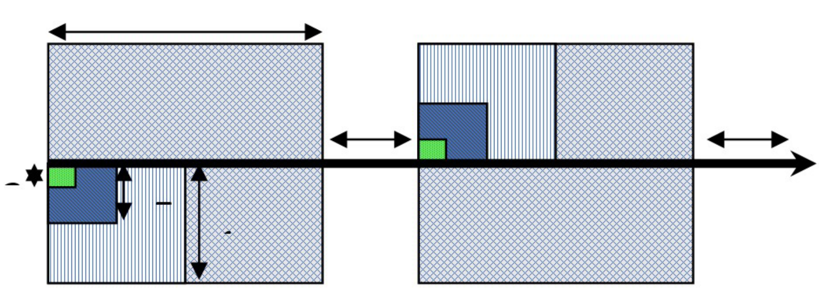

Figure 2. Research Sample Plot Research Sample Plot.

Figure 3. Leaf samples of C. Sintok: (a) leaf sampling, (b) naming the sample according to the sampling location.

Figure 4. Distillation process of *C. sintoc* leaf samples: (a) sample preparation, (b) process of putting the sample into the distillation tube, (c) distillation process, (d) essential oil yield from the distillation of C,sintoc leaf samples.

the efficiency of the proposed method was demonstrated using a four-fold cross-validation test. Each time, one of the two subsets is used as the testing set and the other two subsets are put together to form the training set. The advantage of this method is that it is not important how the data is divided, Each data point appears in the testing set only once and appears in the training set twice. As a result, verification of the efficiency of the proposed method against the overlearning problem can be proved. Model validation is the process of input/output datasets that are not used for ANFIS training. These datasets are presented to the trained model to see how well the trained model works in the prediction model scheme using the ANFIS method.

2.2. Adaptive Neuro-Fuzzy Inference System (ANFIS)

ANFIS was applied in this study because it is easy to understand, adaptable, tolerates inappropriate data, is able to model nonlinear data, and is able to build and apply directly the expertise of experts (Mujiarto et al., 2019). The ANFIS method offers the benefit of modeling the qualitative side of human knowledge and the mechanism of the decision-making process through given commands (Faisal et al., 2012). Since artificial neural networks are based on combined historical data and can predict future events based on that data (Dahal et al., 2013), they have the advantage of being able to recognize certain patterns, learn the unknown, and provide solutions to problems without the need for mathematical modeling (Ogunwolu et al., 2011). ANFIS has the ability to learn through interpretation, which results in a powerful modeling tool, and automatically generates if-then rules with appropriate membership functions.

Figure 5 shows that there are 5 layers where layer 1 is input data consisting of tree diameter, tree height, soil texture, altitude, temperature and humidity. The second layer is the formation of the model by anfis, in layer 3 the data testing process by the anfis application and in layer 4 is the prediction test based on the training data and real data that has been entered into the application and layer 5 is the output of the anfis prediction model results, Figure 5 shows there are two types of nodes: adaptive nodes with square icons and nodes with circle icons. The output of each layer is denoted by Oj, where j is the number of rules and i is the number of layers.

The ANFIS network consists of five layers as follows.

Layer 1 (fuzzy layer)

Each node in layer 1 is an adaptive node, which means that the parameter values can change according to the function of the node:

$$\begin{aligned} 01,1t &= \mu A1(Zt-1) \\ 01,2t &= \mu A2(Zt-1) \\ 01,3t &= \mu B1(Zt-2) \\ 01,4t &= \mu B1(Zt-2) \end{aligned} \quad (1)$$

With (Zt-1) and (Zt-2) are the inputs at the i-th node, Meanwhile, -1 and -2 are the membership functions of each node, 1 serves to express the degree of membership of each input to fuzzy sets A and B, where 1, 2, 1, 2 are linguistic variables. The membership function used is the generalized bell membership function. The generalized bell membership function can be written as follows:

$$\mu_A(x_t) = e^{\frac{-(x_t-c)^2}{2\sigma^2}}$$

$$f\ x; a_i, b_i, c_i = \frac{1}{1+\frac{x-c_i^{2b_i}}{a_i}} \quad (2)$$

Where AND is a set of parameters called premise parameters, By taking the value = 1, only the AND parameter will change during the learning process, Changes in the values of these parameters will also change the generalized bell curve.

Layer 2 (product layer)

Each node in layer 2 is a non-adaptive node, which means its parameter values are fixed. The function of this node multiplies each incoming input signal as follows:

$$O_{2,i} = w_i = \mu A_i(x).\mu B_i(y); i = 1,2 \quad (3)$$

Each output node expresses the activation degree of each fuzzy rule, The number of rules formed follows the number of nodes in this layer,

Layer 3 (normalization layer)

Each node in this layer is a non-adaptive node that expresses the normalized degree function which is the ratio of the output of the I-th node in the previous layer, written as follows:

$$O_{3,1} = w_t \frac{w_i}{w_1 + w_2}, With\, i = 1,2 \quad (4)$$

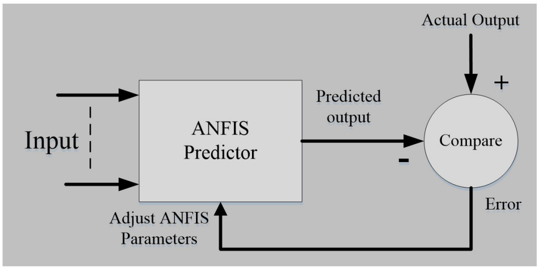

Figure 5. ANFIS Data Input and Output Model Diagram.

This function can be expanded if there are more than two rules by dividing it by the total number w for all rules,

Layer 4 (defuzzification layer)

Each node in this layer is an adaptive node with the following node functions:

$$\begin{aligned} O_{4,1t} &= w_{1t}^{*} Z_t^{(1)} = w_{1t}^{*}\left(\alpha_1 Z_{t-1} + \beta_1 Z_{t-2} + \gamma_1\right), \\ O_{4,2t} &= w_{2t}^{*} Z_t^{(2)} = w_2^{*}\left(\alpha_2 Z_{t-1} + \beta_2 Z_{t-2} + \gamma_2\right) \end{aligned} \quad (5)$$

where, α_i, β_i, γ_i are the set of parameters of the node and are called consequent parameters.

Layer 5 (total output layer)

Layer 5 is the last layer that functions to sum all inputs with the following node functions:

$$O_{5t} = \hat{Z}_t = w_{1t}^{*} Z_t^{(1)} + w_{2t}^{*} Z_t^{(2)} \quad (6)$$

3. Results and Discussion

3.1. Distillation result of C. sintoc leaf

Extraction of *C. sintoc* essential oil was carried out using the water vapor distillation method for 8 hours. Each extraction result was collected based on their respective sampling variables based on the direction of the sampling slope resulting in varying volumes, (Table 1). The average volume of leaf essential oil was largest on the western slope (1,45 ml), followed by the northern slope (1,37 ml), east (1,09 ml), and southern slope (0,88 ml), while the volume of bark essential oil was largest on the western slope (1,82 ml), followed by the northern slope (1,73 ml), east (1,24 ml), and southern slope (1,22 ml). The volume of essential oil of the leaves of *C. sintoc* can be seen from the distillation results in Table 1 below.

Based on Table 1, the average volume of essential oil in the leaves of *C. sintoc* on the western slope has a higher volume on the stem bark compared to the leaves (0,88 - 1,45 ml and 1,22 - 1,82 ml). This condition can be influenced by differences in the plant parts used, This is the same as the research of Budiarti et al. (2018) that the volume of *Cinnamomum burmanii* essential oil produced from the leaves and skin has a difference where the leaves are higher than the skin, Another study (Lova et al., 2018) on clove plants (*Syzygium aromaticum* L,) showed the volume of essential oil in flower parts (3,1 ml), flower stalks (2,7 ml) and leaves (2,5 ml) where the flower part was higher than the other parts.

Furthermore, based on the results of essential oil levels that have been obtained by testing in the laboratory, to obtain predictive data on essential oil levels in *C. sintoc* leaves, analysis is carried out using ANFIS with two stages, namely step forward and step back, The forward step will produce parameter values that improve the consequent parameters in layer four using the Least Square

Table 1. The volume of essential oil of the leaves of *C. sintoc* can be seen from the distillation.

Slope Direction	Altitude	pH	Temperature	Relative Humidity, %	Essential oil volume, mL	Essential oil yield (%)
					Leaves	Leaves
West	600	7,09	28	77	1,25	0,05
	700	5,68	28,5	71	0,73	0,04
	800	6,73	27,5	67	1,63	0,06
	900	5,99	24,5	82,5	1,70	0,07
	1000	6,20	26	77	1,96	0,08
South	500	6,65	26	75	0,87	0,03
	800	6,47	28,5	66	0,87	0,03
	900	6,47	26	71	1,08	0,04
	1000	4,73	24	75	0,67	0,04
	1200	6,34	25	73	0,90	0,04
East	500	6,06	28	82	1,37	0,04
	600	5,88	25	90	0,89	0,04
	700	5,58	26	76	0,79	0,04
	800	5,87	28	72	1,20	0,04
	900	6,21	25	66	1,55	0,06
	1000	5,45	27	68	1,27	0,05
	1100	5,22	25	85	0,59	0,03
North	500	6,54	27,5	73	1,08	0,05
	600	6,82	27	73	1,29	0,05
	700	5,79	28	67,5	1,33	0,06
	800	6,46	27	71	1,18	0,05
	900	6,18	26	75	2,01	0,07
	1000	6,26	26	70	1,33	0,05
Total average					1,20	0,05

Estimator (LSE). While the backward step will propagate the forward value back through Backpropagation using Gradient Descent to improve the premise parameters in layer one, Programming using the ANFIS method is trained by testing the accuracy of this method, between data from the database (average essential oil content) and the output which is the prediction result, The results are quite accurate, indicated by the signs (o and *) being close together and it can be seen that the training plot (blue) follows the pattern of the test data (red) (Figure 6), The small learning rate leads to a larger number of epochs to achieve the same RMSE.

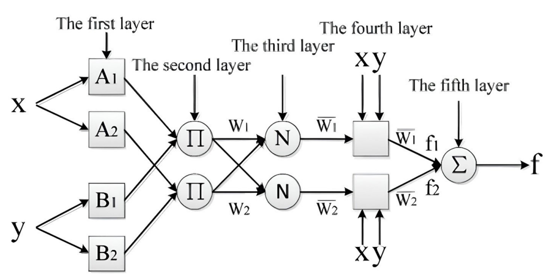

Figure 6. ANFIS Structure Algorithm.

Then the essential oil prediction model with the ANFIS method is built with matrix data, with 26 training data that have been selected, which can represent 31 databases. This matrix consists of inputs and outputs, where there are 6 variables that affect each other for 1 output (Figure 7). Then this method, Design a membership function for each input variable From the data image above is the input data for ANFIS. Then in obtaining a prediction of the output of the predicted volume of essential oil, it takes 729 rules formed from the design of input data to a predetermined output, Input data consisting of Diameter = 3 MF (Memberfunction), Height = 3 MF (Memberfunction). Soil texture = 3 MF (Memberfunction), MDPL Height = 3 MF (Memberfunction). Temperature = 3 MF (Memberfunction) Humidity = 3 MF (Memberfunction) is what affects the prediction of essential oil output on *C. sintoc* trees, Below

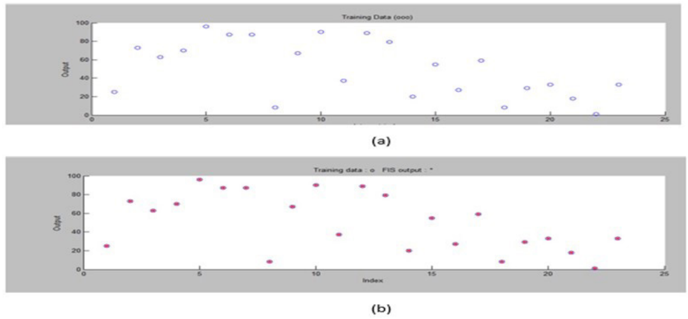

Figure 7. Training error and data: (a) training error, (b) training plan (blue) and testing data (red).

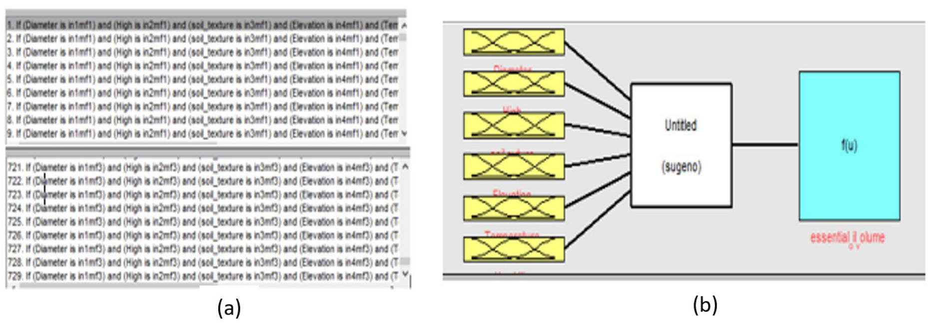

Figure 8. Rule development (a) 729 rules (b) Member Function Input.

is Figure 8 which contains the draft member function and the rules formed from the draft member function input.

Next is the prediction process based on the best data model from the analysis process carried out by ANFIS, namely by using MF as much as 6. In this study, predictions were made on 26 training data compared to the actual available data obtained with the ANFIS structure model (Figure 9). The model mapping shows the influence of inputs on production prediction as output. The most influential input variables in order are: tree diameter, tree height, soil texture, land elevation, temperature, and humidity.

Next is the prediction process based on the best data model from the analysis process carried out by ANFIS, namely by using MF as much as 6, In this study, predictions were made on 26 training data compared to the actual data available. From the prediction results, an accuracy value of 90,99% was obtained. Comparison of actual data with predicted data can be seen in Figure 10. From the prediction comparison graph between actual data and ANFIS trial results, it can be seen that in general the determination results with ANFIS are close to the actual value. Basically, forecasting with data with ANFIS will run well if the data used has a regular pattern, In this study, the data used has a pattern that statistically has a high enough deviation so that ANFIS actually gives an error at a certain point even though it is not too large.

The surface interface for the optimal input and output shown in Figure 11 shows the relationship between diameter, tree height, soil texture, soil height. For Surface Interface (comparative display of the effect of the two

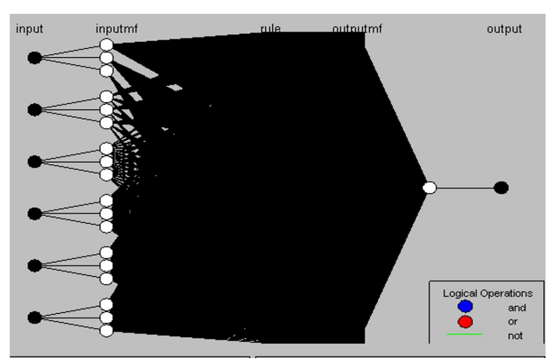

Figure 9. ANFIS model structure ANFIS model structure.

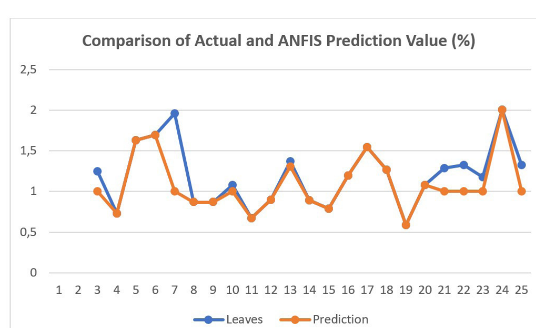

Figure 10. Comparison of Actual and Predicted Values of ANFIS.

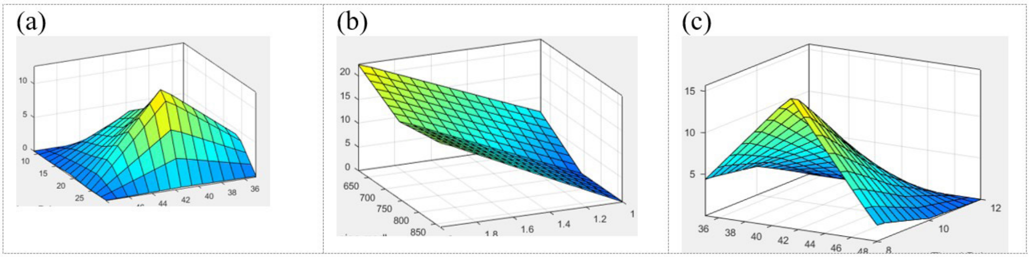

Figure 11, Effect of input variables on output: (a) Effect of diameter variability, altitude on essential oil volume, (b) Effect of field condition variability, altitude on essential oil volume, (c) Effect of temperature and humidity of tree growth conditions on essential oil volume.

inputs on the output). For example, in Figure 11 it can be seen that the influence of tree diameter and tree height, the best range limit to get good essential oil production results, in this case it can be seen when the tree diameter is 42 cm and the tree height is about 15 m, when viewed from the influence of land variables where trees grow to produce high productivity, namely on land in the form of slopes and at an altitude of 650-700 meters above sea level. Meanwhile, when viewed from the physical variables of the tree, the factors that affect productivity are tree diameter and height. The highest productivity is obtained when the tree has a diameter of 42 cm with a height of 15 m, In this study, the highest tree productivity was obtained when *C. sintoc* grew at an altitude of 650-700 masl, tree diameter of 42 cm, height of 12 m, growing on sandy textured land conditions and at a humidity of 75 and at a growing temperature of 260C.

From the results of the ANFIS analysis that has been carried out, it is found that the level of influence of each variable is very close, meaning that tree diameter, tree height, land height, soil texture, temperature, and humidity on essential oil production are very closely related, This is in line with the results of the community assessment that assesses tree diameter, tree height, land height, land shape to the volume of essential oil is very closely related to the amount of essential oil volume. Based on the phenomenon in the field, people in the research area have been able to optimally integrate these beliefs to see trees that are prospective to be used as essential oil producers. Thus, each community can easily determine candidate trees that are considered good enough to produce essential oil, Especially in determining the production design of the total volume of essential oil to be obtained can be done in advance so that it can facilitate the *C. sintoc* farming community.

4. Conclusion

Based on the distillation results, there are differences in the volume of essential oil contained in *C. sintoc* plants according to the ecological and morphological conditions of *C. sintoc* plants. ANFIS prediction results show good accuracy (90,99%), indicating that the variables of tree diameter, tree height, soil texture, altitude, temperature and humidity are the main determinants in determining the essential oil content in *C. sintoc* plants growing in the Mount Ciremai National Park area.

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