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Towards a Computational Model for the Prediction of Rubber Wood Price of a Rubber Plantation

Phanarut Srichetta and Nattaya Mahapo

Dept. Computer Science and Information Technology, UDRU, Thailand
e-mail: phanarut@udru.ac.th
Project Management Dept., Metropolitan Waterworks Authority, BKK, Thailand
e-mail: nattynice@hotmail.com

Abstract

Rubber woods of each rubber plantation have different prices because of several factors such as wood quantity and quality, transportation, and others. The owner of a rubber plantation often gets the unfair price because the purchasers or middlemen may press the wood price according to such uncertainty factors. To help the rubber plantation owner estimates the initial price of his/her rubber wood, this research proposes a computational model for predicting rubber wood price of the rubber plantation. This proposed model consists of two main phases: the class categorization and the price prediction of rubber wood. The class of rubber wood in a rubber plantation can be categorized based on the factors' values of rubber wood. Then the rubber plantations owners and the purchasers can specify their required prices according to the classified class of rubber wood. In the phase of price prediction, the simple regression analysis method was used to predict the rubber wood price based on the collected prices which are the prices the owners offer to sell and the prices the purchasers offer to buy. We experimented our proposed model from 15 test cases of rubber plantations in Thailand. The experimental results showed that the proposed model can be used to predict the price of rubber wood. As a result of the prediction, the rubber farmers can decide to cut rubber trees for sale or to plant rubber trees further.

Keywords: *Computational model, Prediction, Rubber wood, Simple regression analysis, Standard class*

1 Introduction

Rubber wood plays an important role in industrial economy, particularly in the ASEAN region. For Thailand, the rubber wood industry is one of vital industries to generate huge revenues for the country [1]. In general, rubber trees in each rubber plantation are the same age. Therefore, for selling the rubber wood, mostly the farmers will cut and sell all rubber trees in the garden. The rubber wood price in each rubber plantation is different. It depends on several factors such as quantity and quality of wood, transportation, and others [2]. The area size of cultivation, age of harvesting, preservation and environments for planting rubber affect the quantity and quality of wood. Whereas the distance and route condition between a plantation and a lumber factory affect the transportation. In addition, the money actually reaches farmers’ hand may be less due to the labor cost of sawmilling and carriage to lumber factory, and also other costs (if has) such as the cost of making route, the fee of passing way, etc. The purchasers or middlemen may lower the wood price because of these uncertainty factors.

Trading rubber wood from a rubber plantation, in the past and at present, mostly can be done by the price agreement privately between the farmer and the purchasers or the nearest lumber factory. In another direction, the farmers can submit requirements for sale via the rubber wood central market. However, they have to wait for the staffs of such market go out to the plantations and then assess and classify a class for the rubber wood to be sold. The rubber wood central market will inform the minimum price of the assessed wood, according to the standard class, to the purchasers over the internet for making the electronic auction. This process takes quite a long time, so farmers may lost time for waiting until the bidding is finished. Therefore, if there is a method or tool to help the farmers estimate the initial price of rubber wood in their plantations according to the garden conditions and their need, it may help the farmers decide to cut rubber trees for sale or to plant them further. There are several research studies on the prediction of rubber wood data, including forecasting the export values of rubber wood and furniture [3], predicting the mechanical properties of thermally-modified rubber wood [4] and estimating the area, volume and age of rubber plantations [5]. Lack of research that studies the forecasting of rubber wood prices according to the quantity and quality of the plantation.

From the mentioned reasons, the objective of this research is to study and propose a computational model for the prediction of the rubber wood price of a rubber plantation. The price to be predicted is which the owner of the target rubber plantation will receive from the purchaser. Time series of price data is not relevant to this prediction. Statistical techniques used for prediction without considering time series include regression analysis and its various sub-categories such as linear regression, generalized linear models, etc. The regression analysis method [6][7] is used to predict the price of rubber wood. The prediction process is based on the training dataset of the prices wanted by the owners of the rubber plantations and the prices supplied by the purchasers. These specified prices can come from that whether the owners and the purchasers know that what the class of rubber wood of the rubber plantations are. The class can be classified, according to the proposed computational method, based on the factors related to the quantity, quality, and operational management of rubber wood at the plantation. The factors' details related to the class categorization of rubber wood are presented in Section 2. The computational model for predicting rubber wood price at a rubber plantation is proposed in Section 3. This model consists of 2 separated phases. The first phase of this model, the class categorization of rubber wood, is presented in detail in Section 4. The last phase of the model, the price prediction of rubber wood, is presented in Section 5. By the proposed model, experimental studies are conducted and results are reported in Section 6 and the conclusion and discussion are summarized in Section 7.

2 Factors Related to the Class of Rubber Wood

In the rubber wood industry, the class of rubber wood of a rubber plantation is important for determining their price. It is used as an indicator for announcing the rubber wood price in the rubber wood central market. From a survey and study on 25 lumber factories by the Rubber Research Institute of the Department of Agriculture (RRIDA) [2], it is found that 10 important factors (F_1-F_{10}) can be used to categorize the class of rubber wood at a plantation. The explanation of the related factors and the condition values are summarized as follows.

F_1: Average circumference of stems (centimeters) of random 100 rubber trees at the height 170 centimeters

F_2: Average height until crotch of random 100 rubber trees:
  If its value is greater than or equal to 2.50 meters, this factor value is 1, otherwise is 0.5.

F_3: Number of useful rubber trees per rai where their perimeters are greater than 50 centimeters

F_4: Regularity of stem size: The value of this factor can be got by computing the standard deviation (Std.) of circumferences of random 100 rubber trees.
  If its standard deviation value is less than and equal to 18.1, this factor value is 1, otherwise is 0.5.

F_5: Plant area (rais)

F_6: Reachability to the rubber plantation:
  If a car can reach the plantation by standard road, this factor value is 1.
  If a car can reach the plantation by soil road having a little bit holes, this factor value is 0.75.
  If a car can reach the plantation by soil road only, this factor value is 0.35.
  If a car can’t reach the plantation or we must walk through other plantation instead, this factor value is 0.

F_7: Difficulty/Easiness to operate in a plantation area:
If it is very easy to operate on the totally plain area, this factor value is 1.
If it is easy to operate with intermediate level, this factor value is 0.5.
If it is difficult to operate on the high slop area, this factor value is 0.

F_8: Damage of the front of cut rubber:
If the damage is very high, quite high, intermediate, few and very few, then this factor value is 1, 2, 3, 4 and 5, respectively.

F_9: Rubber species in a plantation:
If there are same rubber species more than 80%, this factor value is 1.
If there are mix rubber species, this factor value is 0.5.
If there are same rubber species of BPM24, this factor value is 0.

F_{10}: Age of rubber trees ready to cut (years)

These factors are divided into 3 aspects: quantity, operation, and quality. They were studied by the RRIDA in order to find the weight values used for categorizing the class of rubber wood. The discovered percentage of importance plus/minus the standard error (SE) of each factor, called weight (W_i), obtained from the study on 25 lumber factories is summarized and reported as shown in Table 1. Moreover, each factor also has a standard value (S_i) discovered from the survey and study on 100 random rubber trees from 50 sample rubber plantations in the South region of Thailand.

Table 1. Weight and Standard Value of Each Factor

Factors		Weight (W_i)	Standard Value (S_i)
Quantitative Factor	F_1	47 ± 4.95	80 centimeters
	F_2	5 ± 1.49	1
	F_3	5 ± 1.79	56 rubber trees
	F_4	3 ± 0.25	18.1
	F_5	2 ± 0.20	11.5 rais
Operational Factor	F_6	7 ± 1.34	1
	F_7	8 ± 2.33	1
Quality Factor	F_8	8 ± 1.97	5
	F_9	10 ± 2.52	1
	F_{10}	5 ± 1.16	21 years
Total		100	

The weight and standard values of these factors are important for categorize the class and specify the minimum price of rubber wood. This will lead to the price forecast for rubber wood.

3 The Proposed Computational Model for Predicting the Rubber Wood Price at a Rubber Plantation

This research proposes the computational model for predicting the rubber wood price of a rubber plantation. This model consists of 2 main phases: the class categorization of rubber wood and the prediction of rubber wood price. The details of each phase are presented as shown in Fig.1.

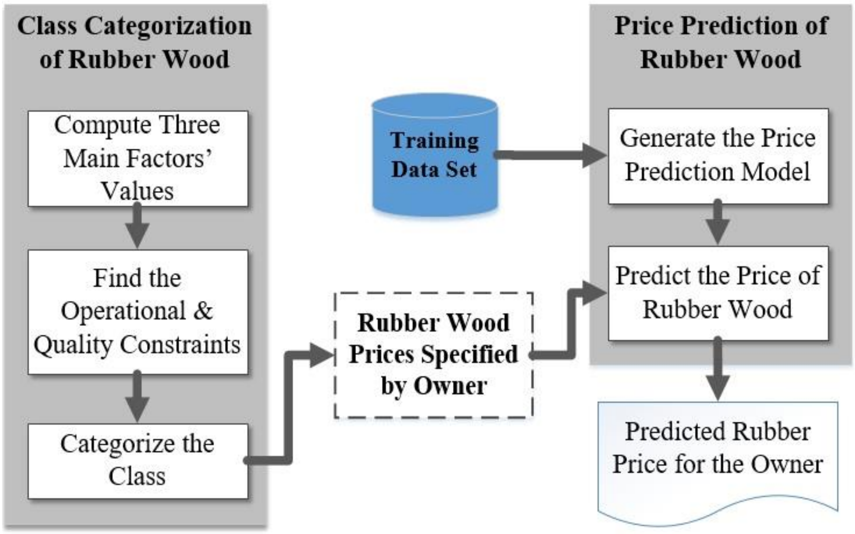

Fig.1 The Proposed Computational Model for Predicting Rubber Wood Price at a Rubber Plantation

From Fig.1, the data input to the phase of class categorization of rubber wood are ten factors' values of a rubber plantation including their weights and standard values. This phase consists of three steps including computing three main factors' values, finding the operational and quality constraints, and categorizing the class of rubber wood. The detailed class categorization of rubber wood in each step is described in Section 4. Once knowing the class of rubber wood, we will know the current minimum price of the rubber wood announced by the rubber central market. In order to know the price predicted from the phase of price prediction of rubber wood, the owner of the rubber plantation shall specify the required price for sale after he/she know the class and minimum price of the rubber wood. In this phase, however, the price prediction model must be generated firstly based on the training data set. Then, predict the price of rubber wood for the owner of the rubber plantation to be obtained according to the generated model. The details of the phase of price prediction of rubber wood will be described in Section 5.

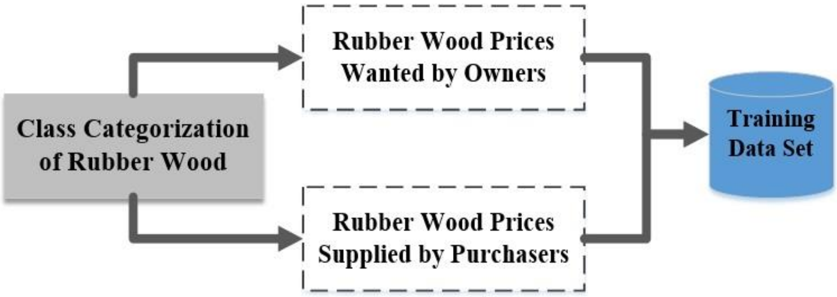

Fig.2 Preparation of Training Data Set

For the training data set, it includes the prices of rubber wood wanted by the owners and the prices supplied by the purchasers for each rubber plantation. These prices at each rubber plantation exactly are surveyed and collected after knowing i) the class of rubber wood obtained from the phase of class categorization of rubber wood and consequently ii) the current minimum price of the rubber wood announced by the rubber central market.

4 Class Categorization of Rubber Wood at a Rubber Plantation

To categorize the class of rubber wood at a rubber plantation, the following 3 steps will be taken: compute main factors' values, find the operational and quality constraints, and categorize the class of rubber wood.

4.1 Computing Three Main Factors' Values

There are 3 main factors that are important for categorizing the class of rubber wood at a plantation. They are the quantitative, operational and quality factors. The values of these 3 main factors can be computed by using equation (1) where k =1, 2 and 3 based on the initial factors' values, the weight and the standard value.

$$V_k = \left[1 + \sum_{i=x}^{y} W_i \; x \; ((F_i / S_i - 1)\right] x \; 100 \tag{1}$$

- To calculate the quantitative factor value (V_1), assign x=1 and y=5.
- To calculate the operational factor value (V_2), assign x=6 and y=7.
- To calculate the quality factor value (V_3), assign x=8 and y=10.

4.2 Finding the Operational and Quality Constraints

4.2.1 Operational constraint

The operational value (OP) is used to specify that such a plantation whether has or has not the operational constraint. If $V_1 \leq 86$, then the plantation has the operational constraint (OP=H), otherwise it doesn't has (OP=DH).

4.2.2 Quality constraint

The quality value (QL) is used to specify that such rubber wood whether have or have not the quality constraint. If $V_2 \leq 90$, then the wood in the plantation have the quality constraint (QL=H), otherwise they don't have (QL=DH).

4.3 Categorizing the Class of Rubber Wood

The standard class of rubber wood can be categorized into 16 classes (1A - 4A, 1B - 4B, 1C - 4C, 1BC - 4BC) based on the computed quantity value (*V_1*), and the operational and quality constraints (*OP* and *QL*). The criteria for categorizing the class are presented as follows.

$$level = \begin{cases} '1' & , if\ 103.0 \leq V_3 \\ '2' & , if\ 99.0 \leq V_3 < 103.0 \\ '3' & , if\ 94.0 \leq V_3 < 99.0 \\ '4' & , otherwise \end{cases} \tag{2}$$

$$class = \begin{cases} level + 'BC' & , if\ OP = H\ \&\ QL = H \\ level + 'C' & , if\ OP = DH\ \&\ QL = H \\ level + 'B' & , if\ OP = H\ \&\ QL = DH \\ level + 'A' & , if\ OP = DH\ \&\ QL = DH \end{cases} \tag{3}$$

5 Price Prediction of Rubber Wood

In order to predict the price of rubber wood, the following two steps will be taken: generating the price prediction model and using the model to predict the price of rubber wood to the rubber farm owner. The most important step is the step of modeling the price prediction. There are only two variables involved: the price of the rubber wood required by the rubber plantation owner, and the price at which the purchaser responds to the seller. Not relevant to the time period. In this research, the researchers are interested in studying the relationship between one independent variable which is the price of rubber wood the owner wants to sale and one dependent variable which is the price of rubber wood the purchaser wants to pay. Initially, the researchers have studied that these two variables have positive linear correlation, based on the Pearson's correlation coefficient r [8], with acceptable level. It is noted that this coefficient has a value between 1 and -1 where 1 is total positive linear correlation, 0 is no linear relation, and -1 is total negative linear correlation. Therefore, the simple linear regression analysis method is applied in this research paper.

Simple linear regression analysis is a method for obtaining a formula to predict value of one variable from another variable where there is a causal relationship between the two variables [6][7]. It can be applied in various fields, such as business, engineering, economics and science [9][10][11][12]. Especially in agriculture, the linear regression analysis is applied in many research such as to establish relationship between explanatory variables (area under cultivation, annual rainfall and food price index) and to predict the crop yield [13], to calculate the effect of the total agricultural machinery dynamic and total crops planting area in the total output of farming, forestry, animal husbandry and fishery industries [14], to predict the crop production [15], etc. The important part of simple linear regression is the formula of a straight line which provides the predicted response for a given predictor variable value. It is most commonly represented as the following equation

$$y = \beta_0 + \beta_1 x \tag{4}$$

where y is the dependent (or response) variable, x is the independent (or predictor) variable, and β_0 and β_1 are intercept and slope parameters of the model respectively. They are usually called as regression coefficients that need to be estimated from previous set of data x and y where

$$\beta_1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} x_i^2 - n(\bar{x})^2} \tag{5}$$

$$\beta_0 = \bar{y} - \beta_1 \bar{x} \tag{6}$$

To predict the i^{th} individual response variable y_i when knowing the individual's score of a predictor variable x_i, the model to be used is given in the form

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i \tag{7}$$

where β_0 and β_1 are regression coefficients, and ε_i is the residual (error) term that represents the different between the true value x_i and the predicted value y_i, i =1, 2, …, n. The error of the linear regression model is the sum of all errors of the test data. It can be noted that a fitted model can be said to be good when residuals are small. When intercept term (β_0) is presented in the model, a measure of goodness of fit of the model is the proportion of variability that is not covered by the regression. It is known as the coefficient of determination, called the R square

(R^2). A value of R^2 closer to 1 indicates the better fit and value of R^2 closer to 0 indicates the poor fit.

6 Experimental Study and Result

The proposed computational model was conducted to find the results. Therefore, this section presents the data collection and preprocessing data of rubber wood at the rubber plantations and the results of the phases of class categorization and price prediction of rubber wood.

6.1 Collecting and Preprocessing Data of Rubber Wood

To collect the experimental data, we prepared the data collection form for the rubber plantations. The case studies used in this research are 15 rubber plantations in Thailand which have rubber trees ready for sale. Questions in the data collection form ask about basic information of the rubber plantations related to 10 factors of rubber wood as mentioned. The owners of the rubber plantations (and/or the researchers) can collect data of random 100 rubber trees together about their stem circumference and the height until crotch. The next step is to transform the collected data into the corresponding factors values as illustrated in Table 2.

Moreover, we also collected the prices of rubber wood of those rubber plantations which the owners want to sale and the prices which the purchasers want to pay. These prices are collected and kept in the data repository after the class of wood at each rubber plantation are categorized according to the proposed model in the phase of class categorization of rubber wood.

6.2 Categorizing the Class of Rubber Wood

The prepared dataset in Table 2 is subsequently used to categorize the class of rubber wood in each rubber plantation. Table 3 shows the computational results of each step of the class categorization phase including three main factors' values (V_1-V_3), operational and quality constraints (OP & QL), and the class of rubber wood.

From Table 3, the weights (W_i) used to compute three main factors' values in this experimental study are only the normalized percentages of importance without plus/minus the SE. These normalized values are in the range [0, 1]. It can be seen that the classes of rubber wood of 15 rubber plantations are not cover all 16 classes. Rubber wood of some rubber plantations are categorized in the same class and some classes are not categorized for any rubber wood such as there are no classes 1A, 1B, 4C, 3BC and 4BC. The classes are categorized depend on the different/similar environmental factors of the rubber plantations.

Table 2. Preprocessed Dataset of Rubber Wood at Fifteen Rubber Plantations

No.	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
1	75.13	1	42	0.5	14	0	0	4	1	20
2	80.00	1	58	1	30	0	0	1	0.5	23
3	78.84	1	52	1	20	0.75	0.5	4	1	22.5
4	72.36	1	48	0.5	10	0	0	3	0.5	20
5	73.97	1	59	1	15	0.35	0	4	0.5	22
6	80.33	1	53	1	8	0.75	0.5	4	0.5	25
7	78.50	1	58	1	34.5	0.75	0.5	4	0	21
8	81.02	1	55	0.5	12	0.35	0.5	3	0.5	20
9	72.64	1	56	1	35	0.35	0	4	0	21
10	74.91	1	58	1	22	0.75	0.5	4	1	21.5
11	73.05	0	49	0.5	28	0.35	0	2	0.5	24
12	74.89	1	44	1	40	0	0	4	1	21
13	80.56	1	48	1	12	0	0	3	1	21.5
14	79.63	1	50	1	16.5	1	0.5	3	1	22
15	78.76	0	48	1	25	1	1	3	0	21

Table 3. Finding Results of Each Step of Categorizing the Class of Rubber Wood

No	Three Main Factors' Values			Constraints		Class of Wood
	V_1	V_2	V_3	OP	QL	
1	94.82	85.00	98.16	H	DH	3B
2	103.40	85.00	89.08	H	H	1BC
3	100.44	94.25	98.76	DH	DH	2A
4	93.04	85.00	91.56	H	DH	4B
5	97.33	87.45	93.64	DH	DH	3A
6	99.32	94.25	94.35	DH	DH	2A
7	103.30	94.25	88.40	DH	H	1C
8	99.10	91.45	91.56	DH	DH	2A
9	99.76	87.45	88.40	DH	H	2C
10	99.01	94.25	98.52	DH	DH	2A
11	91.66	87.45	90.91	DH	DH	4A
12	100.88	85.00	88.40	H	H	2BC
13	99.70	85.00	96.92	H	DH	2B
14	100.10	96.00	97.04	DH	DH	2A
15	95.91	100.00	86.80	DH	H	3C

6.3 Predicting the Rubber Wood Price

Within this phase, the collected dataset of the required and response prices of these 15 rubber plantations are used to generate the prediction model. First of all, the required prices from the owners and the response prices from the purchasers are studied in order to find the trend of correlation among them. Therefore, we do the scatterplot for finding such trend.

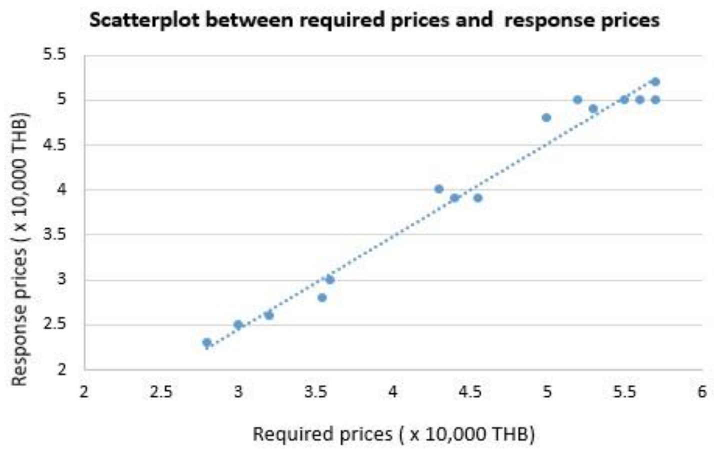

Fig.3 Scatterplot between the required and response prices of rubber wood at the rubber plantations

The trend of correlation, as shown in Figure 3, seems to be linear. Therefore, we calculate the correlation coefficient between these two prices and show the result in form of matrix in Table 4.

Table 5. Correlation Coefficient between the Required Prices and the Response Prices

Correlation Coefficient	Required Price	Response Price
Required Price	1	
Response Price	0.988738	1

The important value is 0.988738 which is the correlation coefficient between the required prices and the response prices. It means that these two prices have more positive correlation in linear manner.

Table 5. Model Summary of the Required Price

R Square	Adjusted R Square	Standard Error
0.977604	0.978551	1683.413

Table 5 indicates goodness of fit R square =0.977604, adjusted R square is 0.978551, both are near to 1, which indicates that the model fits well. And the standard error of the estimate is 1683.413.

Table 6. Regression Coefficient Values

	Coefficients	Standard Error	t Stat
Intercept (β_0)	-6491.3814	1996.7593	-3.2510
Slope (β_1)	1.0332	0.0434	23.8213

From Table 6, the intercept β_0 is -6491.3814 and the slope $\beta 1$ is 1.0332. The t-test of coefficients significance, is to test whether independent variable x_i impacts dependent variable y significantly. Put forward null hypothesis and alternative hypothesis as followed: H_0: $\beta_1=0$ and H_1: $\beta_1 \neq 0$. For independent variable X (Required Price), the estimation of its regression coefficient is 1.0332, standard error is 0.0434, t-test value is 23.8213. Therefore we refuse H_0 and think independent variable X is highly significant. So, Y= -6491.3814 + 1.0332X is the price prediction model of this experimental study.

7 Conclusion and Discussion

From the study of the standard class categorization of rubber wood, the central price of rubber wood and the real obtained money of farmers from the sale of rubber wood, it leads to the experiment to predict the price of rubber wood for the target farmer. The experiment is conducted from the proposed computational model for the price prediction of rubber wood of a rubber plantation. At the first phase of model, the class categorization of rubber wood, the factors related to the wood quantity, operation of rubber plantation, and wood quality have been used to categorize the class. At the phase of price prediction, the simple regression analysis method is used to predict the price of rubber wood for the target owner based on the prices dataset given by other owners and purchasers. The experimental study results showed that the proposed model can be used to predict the price of rubber wood. As a result of the prediction, the rubber farmers can decide to cut rubber trees for sale or to plant rubber trees further.

Although the number of case studies of the rubber plantations is not much and the number of categorized classes of rubber wood is not cover all, however this proposed computation model certainly covers the categorization of all classes of rubber wood. This is due to the fact that the researchers and the owner of a rubber plantation did not know in advance what the rubber plantation is in any class before. We will know the layer of rubber after we collect the factors and calculate. But most importantly, it is at the stage of price prediction modeling. The results of the prediction are more accurate when the number of independent variables (response prices) are more. So, what should be further research is to increase the number of rubber plantations to cover every rubber wood classes and then to have a more accurate forecasting model.

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