CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Pine forests account for 17% of total area of plantation forests in Thua Thien Hue Province. They contribute about 59% of forestry volume in the province. Pine tree is one of the most important plantation species since it contributes to the generation of income for its high export value products. The main benefit of pine forest is resin extraction, which has high export value therefore the area of this forest, which is pine forest for resin extraction, is quite high, about 88.6% of total pine forest areas. They also provide the main role in environmental protection and soil conservation as well as for landscape tourism. A large area (about 74%) of the pine forests are at the age between six and 20 years old. The forests at the third level of age (from 11 to 15 years old), which are most vulnerable to pine caterpillar outbreak, occupies about 37% of the total pine forest area. High density in the pine forests has been one of the obstacles on protecting them from the attacks of the pine caterpillar. In a majority proportion (about 85%) the density was greater than 700 trees/ha about. The high density and the forest age distribution are the suitable conditions for pine caterpillar outbreak when they the weather conditions are flavor. In short, the forest structure of the forests (age and density) is one of the decisive factors the probability of the outbreak and the level of damage. The study covered four districts where had about 89% of total pine forest areas and about 97% of pine forest for resin extraction purpose.

In Thua Thien Hue province, the first outbreak of pine caterpillar occurred in 1987, although the first observation of the pest was recorded in the early of 1980s. It was recorded the pine caterpillar outbreak occurred in 12 years during the 17 year period from 1987 to 2003 (the frequency of the outbreak by time during that period was about 70.6%). The outbreak of pest was more frequent from 1987 to 1996. The

area infected by pine caterpillar outbreak was different in different years. The largest infected area was about 1,250 ha in 1989. After that, the infected area reduced gradually and the smallest infected area of about 2.7 ha was recorded in year 2003. During the 17 years period, more than 5,540 ha of pine forest were affected by pine caterpillar. In general, the outbreak of pine caterpillar main occurred in the forest aged from five to 16 years old in the province, and the time from November to February. Over the 17 years period, about 95% of pine caterpillar outbreak happened to the forests aged between five and 15 years old. The highest frequency of epidemic occurrence was recorded in the forest age at level three (between 11 and 15 years old), followed by the forest age level two (between six and 10 years old). That can be concluded that forest age is one of the factors affecting to the outbreak of pine caterpillar in Thua Thien Hue province. This result will give forestry scientists and forestry managers a guide in making decision for pest management. It is suggested that the priority and attention should be given to the pine forests aged from six to 15 years old, especially from nine to 13 years old. The period from December to January in the year made up about 77% of epidemic occurrences. However, during the time, other factors such as food resources, natural enemies may also had affect on the outbreak of pine caterpillar.

In addition to above factors, weather factors had strong affect on the outbreak of the pest. The highest temperature had the closest relationship with pine caterpillar epidemic, followed by total rainfall, relative humidity and number of sunshine hours in months. However, the affect of these factors in different months was different. By using multiple regression analysis, 14 models were developed. According to the model validation result, the study suggested to use the model was developed by using forest age, humidity in June, Sunshine duration in June, averaged air temperature in June, maximum air temperature in August, September, and November, minimum air temperature in September, and total rainfall in September and October, to predict the density of larva in December for pine forests in this area (Thua Thien Hue province).

By using binary logistic regression, on the other hand, another 14 models were developed. The result of model validation by using the classification table and symmetric test showed that the most appropriate model could be model resulted from

considering total rainfall in some months (August and October) as key element and the model based on forest age, total rainfall in July, August and October, Sunshine duration in June, and humidity in September. These models can be used as helpful tools for foresters and forestry management agencies to predict and prevent the pine caterpillar outbreak.

It can be concluded that statistical models can be developed to predict not only for larvae density but also for probability of epidemic occurrence. The larvae density in December can be derived by using the model 1.3, which used multiple linear regression with forest age, humidity in June, Sunshine duration in June, averaged air temperature in June, maximum air temperature in August, September, and November, minimum air temperature in September, and total rainfall in September and October. The probability of epidemic occurrence can be identified from the model 2.2.5, which used binary logistic regression with total rainfall in August and October and model 2.3 which based on forest age, total rainfall in July, August and October, Sunshine duration in June, and humidity in September. Though these models are most appropriate models because they had high correlation coefficients and low errors, the models need to be remodeled and tested with other factors such as level of natural enemies, biomass of pine-leaves, other factors because the coefficient of determinations are not high enough and the RMSE are still high. It means that the developed models could not represent fully all cases, and it also means that the models did not cover all required independent variables to explain the real world. The limitation of this study was that there was not enough data collected in every month. Moreover, very few variables were selected. This has been one of the reasons that made the developed models unsatisfied under all circumstances. In addition, it is necessary to add some more independent variables to or refine binary logistic regression model because the percentage of correct is not fairly high, especially the accuracy for predicting the epidemic occurrence. It means that there may be other factors affecting the outbreak of pine caterpillar that this study has not found out or suggest yet. It is recommended that this should be studied further in future.

7.2 Recommendations

The developed models were appropriate under certain conditions. The models should be used within the province. In addition, they should be used for predicting the larvae density and the probability of epidemic occurrence for the merkus pine species forest with the age of forest have as classified in this study. It is necessary to test the appropriateness of the models if the weather conditions, pine species and forests ages are different from those used in the study.

Due to the limitations of data collection that led to risks in predicting the density of larvae and the probability of pine caterpillar epidemic occurrence, the following recommendations are given to improve the accuracy of the prediction from the models.

Although the data were collected for the period of 17 years, the larvae density was recorded only in December. Therefore, it is strongly recommended that the larvae density should be recorded every month to modify the relationship between larvae density and weather factors. It will help to explain every cases as well as every development stages of the pine caterpillar.

The weather factors were collected on monthly basis that caused difficulty in determination of the pest development as the pest developments usually depend on the daily conditions of the weather factors. It is, therefore, suggested that the models based on the daily weather factors, or degree-day, or heat summations should be set up to compare with. If the difference between the monthly weather data- based models and other models is not significant, it is recommended that the monthly weather data based models should be used since the method of data collection used under these models are very simple.

The development and growth of the pests in the nature are affected by many elements, not only weather factors, food resources but also the natural enemies. Natural enemies maybe the main factor that control the outbreak of pest population,

especially pine caterpillar. So it is suggested that for any study in future, it is necessary to consider the level of natural enemies population as a main element in setting models.

The models were set up only in one province. The weather factors, were therefore, not remarkably various between different models. This maybe causes the bias when the models were developed. The results would be better if the model were developed in different provinces where the weather conditions are various and different.