

The potency of an automated detection system for real-time pest monitoring from smartphones and spatial analysis for leaf-eating caterpillar attack evaluation

Henny Hendarjanti^{1*}, S W Indratno², U T Ismunandar¹ and M H Sugeng W¹

¹PT Astra Agro Lestari Tbk. Jalan Pulo Ayang Raya Blok OR/I, Kawasan Industri Pulo Gadung, Jakarta Timur, Indonesia

²Bandung Institute of Technology, Statistics Research Group, Jalan Ganesha 10, Bandung, Indonesia

*Email: hennyhendarjanti@yahoo.com

Abstract. An early warning system in the oil palm cultivation is needed to know the early existence of pest quickly, precisely and accurately. The automated report is needed because manually or conventional methods of the pest existence in the field are not optimal and accurate. A web-based automatization is programmed for giving early information about pest and the potential natural enemies through daily report using the web which is integrated into the database. Moderate and severe pest attack will inform by short message services. So that, it is easier for management to know pest, natural enemies, and conservation beneficial plants. The data can also be used as a reference for controlling, evaluating, and making a decision as well as knowing real-time conditions exactly, quickly, and accurately. This technique is very important especially for controlling leaf-eating caterpillar and conserving its natural enemy's population in the field.

1. Introduction

The oil palm production has an important role for plantation and economic sector in Indonesia. One of the important problems in the oil palm plantation is pests which cause fruit bunch damage. The leaf-eating caterpillars eat oil palm leaf that causes a decline in the palm oil production. Reducing the amount and frequency of pesticide applications could not only help to reduce some of the unintended impacts of agricultural practices, but also could save time, labour and cost for the growers [1-3].

The early warning system is needed to minimize losses caused by the pest and to know the existence of natural enemies. This research applied automated detection system with web-based, Android, and spatial analysis. Non-stationary time series modelling, especially the family of autoregressive models used to predict the number of pests based on their historical data. We realized that there is some uniqueness of these pest data, i.e. the spike value that occurs almost periodically [4-6]. Through some simulations and case study, we obtained that the selection of constants factor has a significant influence on the model so that it could shoot the spikes value precisely.



2. Automated Early Warning System Processes

Mobile Early warning system was a daily application that has been used for pest and diseases observation. The application used gadgets based on Android with special design for PT Astra Agro Lestari Tbk. The data informed of the coordinate position of field condition actually through GPS. The recorded GPS data in the gadgets were transferred to the OTG USB device, after that the data were sent online and connected to the head office so that the data report was observed and analysed especially for the moderate and severe attacks, and directly communicate using SMS (short message services) [7].

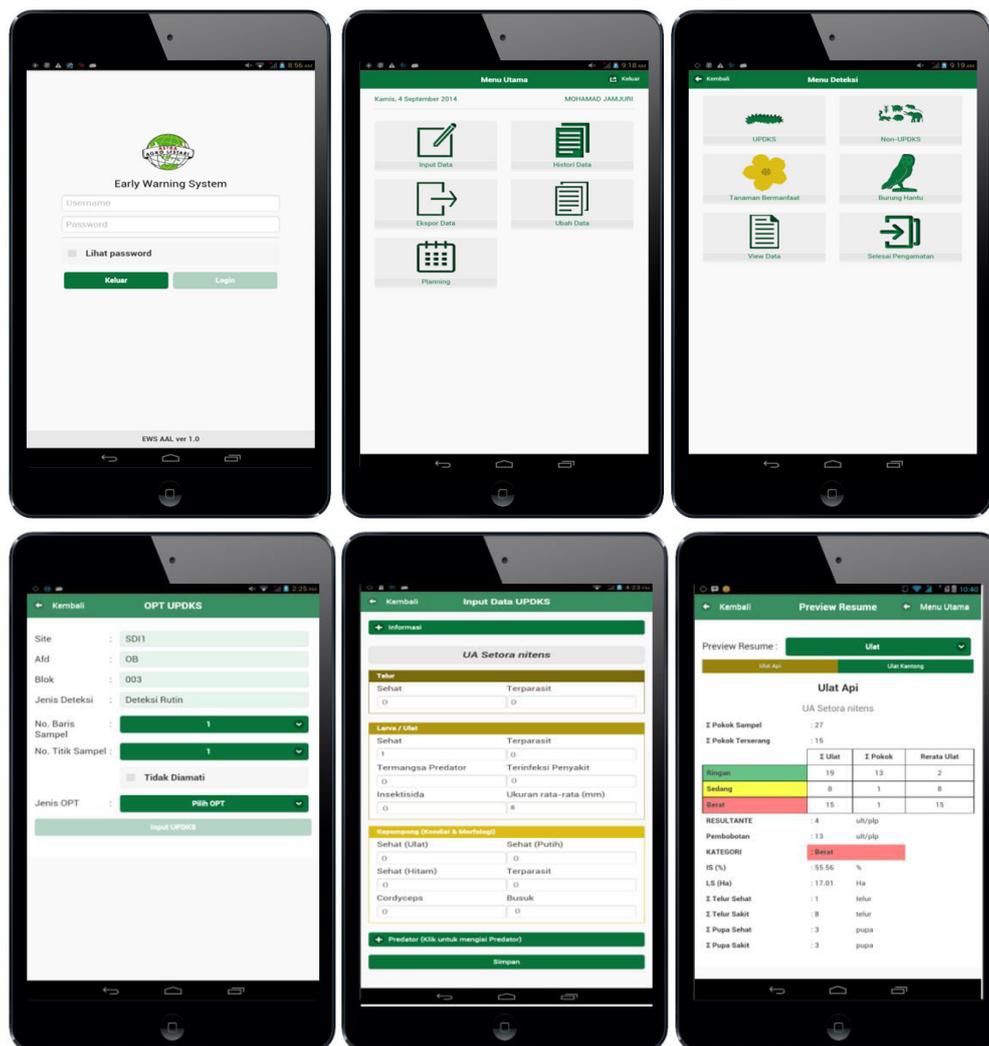


Figure 1. The mobile early warning system of Astra Agro Lestari, Tbk.

3. Automated Spatial Analysis

Through the automated early warning system, we conducted some statistical analysis related to the most recent field conditions. The automated system provides us with the following information, i.e: time series data, statistical descriptive data, and the spatial data of the pest as given in **Figure 2, 3, 4, 5, 6** and **7**.

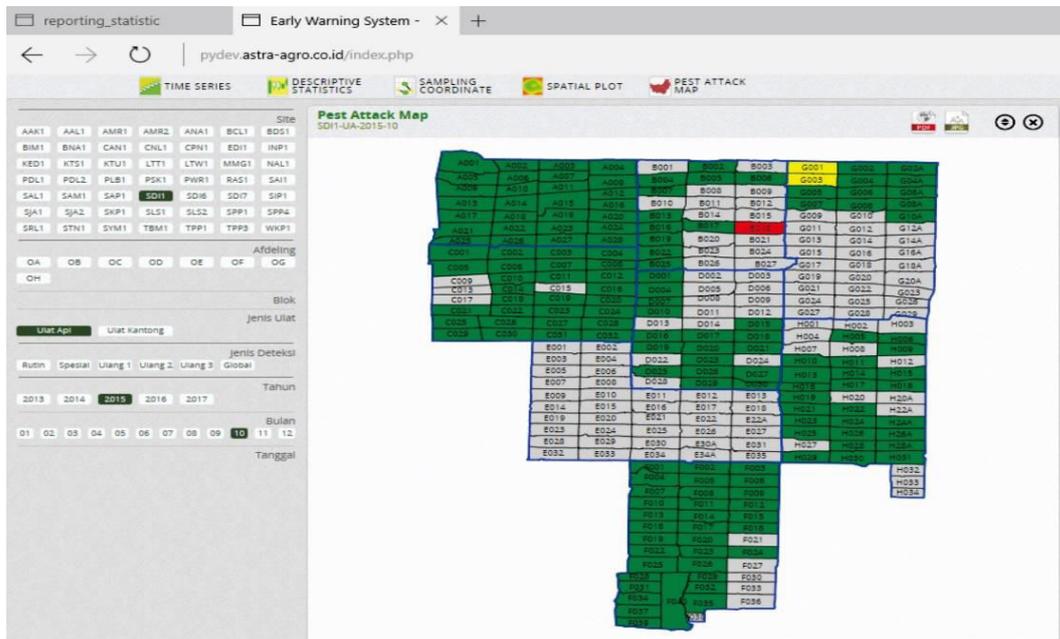


Figure 2. Areas of observation.

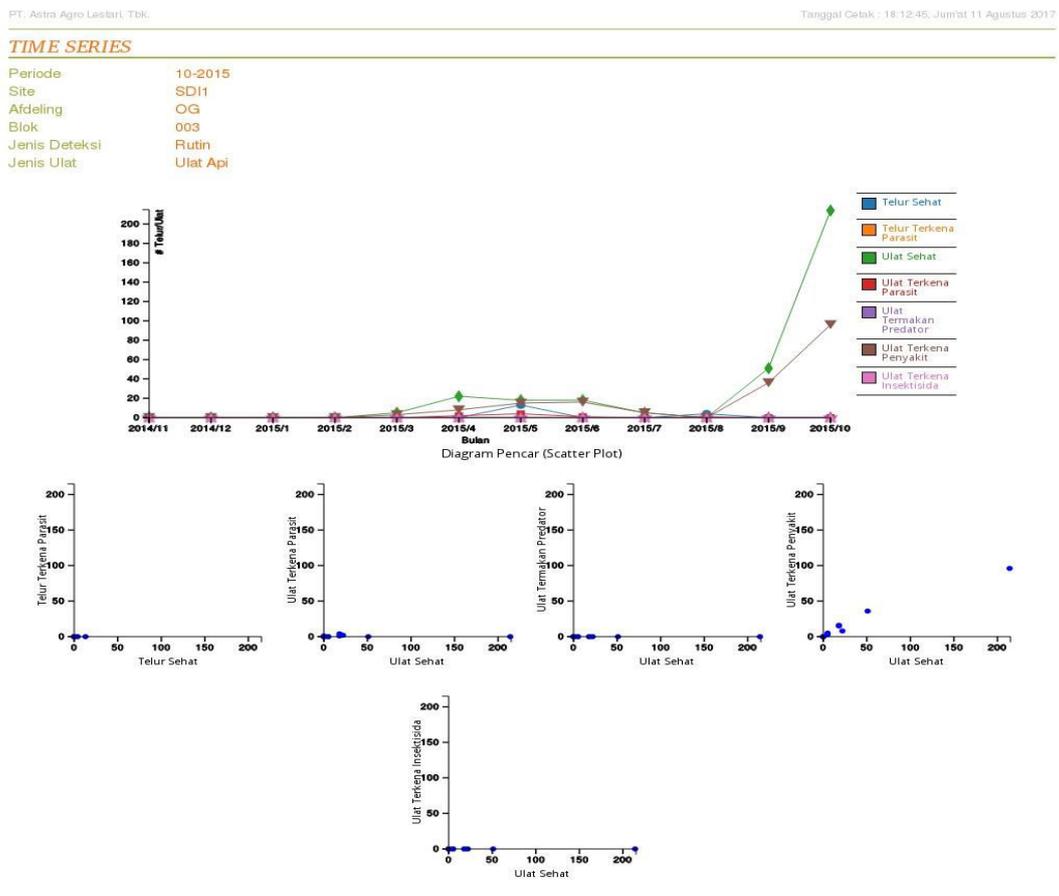


Figure 3. Time series data.

Figure 2 showed a visual representation of the automated early warning system. From the **Figure 2**, we chose an observation at each area, where the system provided the most recent reported data of the pest. From the reported data a map was made in the different colour which was red for severe, yellow for moderate, green for light, and grey for none.

The time series data help us in investigating the behaviour of pests based on time where we could check whether the pest has a pattern at particular months (**Figure 3**) [8]. Moreover, the system also gives a prediction of the number of pests based on the historical data. This prediction helps the decision maker to make a future plan related to preventing damages caused by the pest. In modelling the time series and prediction we applied the Zero-Inflated Poisson (ZIP), model. This model suitable for modelling time series of count where the occurrence of zero counts is higher than the non-zero count. In this model we assumed that the number of pests followed mass distribution function :

$$P(Y_t = k) = \begin{cases} \pi + (1 - \pi)e^{-\lambda} & , \text{for } k = 0 \\ \frac{(1 - \pi)(\lambda^k e^{-\lambda})}{k!} & , \text{for } k \neq 0 \end{cases}$$

where Y_t is the number of pests at a time t , π is the probability of extra zero and λ is the expected Poisson count. The previous information in the model based on the equation $\lambda_t = e^{\alpha_0 + \alpha_1 Y_{t-1}}$, where α_0 and α_1 are parameters which are estimated based on the historical count data [9, 10].

PT. Astra Agro Lestari, Tbk.

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Descriptive Statistics

Periode 10-2015
 Site SDI1
 Afdeling OG
 Blok 003
 Jenis Deteksi Rutin
 Jenis Ulat Ulat Api
 Tanggal Pengamatan 23 Oktober 2015

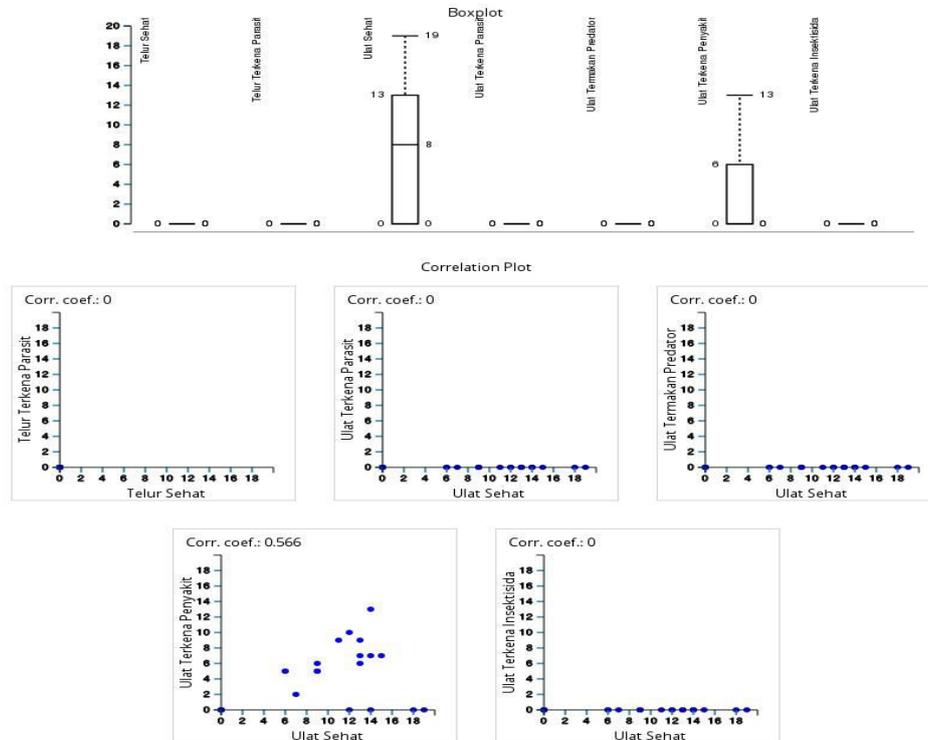
Banyaknya Titik Sample 30

	Telur Sehat	Telur Terkena Parasit	Ulat Sehat	Ulat Terkena Parasit	Ulat Termakan Predator	Ulat Terkena Penyakit	Ulat Terkena Insektisida
#	0	0	214	0	0	96	0
Rataan	0	0	7.1333	0	0	3.2	0
Rataan bersyarat	-	-	11.8889 18	-	-	6.8571 14	-
Modus	0	0	0	0	0	0	0
Median	0	0	8	0	0	0	0
Minimum	0	0	0	0	0	0	0
Maximum	0	0	19	0	0	13	0
Jangkauan	0	0	19	0	0	13	0
Simpangan Baku	0	0	6.5692	0	0	3.9252	0
Variansi	0	0	43.154	0	0	15.4069	0
Skewness	0	0	0.1197	0	0	0.7839	0
Kurtosis	-3	-3	-1.4622	-3	-3	-0.5812	-3
Kuartil Ke-1	0	0	0	0	0	0	0
Kuartil Ke-2	0	0	8	0	0	0	0
Kuartil Ke-3	0	0	13	0	0	6	0

Figure 4. Descriptive statistic.

Another feature provided by the automated early warning system is the descriptive statistic given in **Figure 4**. Using this feature, we observed the basic statistics of the pest data, such as the mean, standard deviation, skewness, kurtosis, boxplot, and scatter plot. Descriptive statistics is a powerful tool in analyzing the distribution of the pest. Then we observed in a particular area how the pest data were spread. The outliers' data also helped us to check an unusual pattern (**Figure 4**). The boxplot was built based on the first (Q_1), second (Q_2) and third (Q_3) quantiles of the data. We labeled the data as outliers if the value was lower than the value of $\min(Q_1 - 1.5 \times (Q_3 - Q_1), X_{(1)})$, where $X_{(1)}$ is the

smallest value of the data, or the value is larger than the value of $\min(Q_3 + 1.5 \times (Q_3 - Q_1), X_{(n)})$, where $X_{(n)}$ is the largest value of the data.



IT Division

Figure 5. Boxplot and scatterplot.

Correlation between stages of the pest showed visually by scatter plots given in **Figure 5**. The correlation of stages of the pest was represented by the coefficient correlation. The closer this coefficient correlation to one, the stronger the linear relationship. But the small the coefficient correlation gave the weaker linear relationship between the two stages. The correlation between X and Y , $\rho_{X,Y}$, is based on the following formula:

$$\rho_{X,Y} = \frac{n \sum_{i=1}^n x_i y_i - \sum_{i=1}^n x_i \sum_{i=1}^n y_i}{\sqrt{\left(n \sum_{i=1}^n x_i^2 - \left(\sum_{i=1}^n x_i \right)^2 \right) \left(n \sum_{i=1}^n y_i^2 - \left(\sum_{i=1}^n y_i \right)^2 \right)}}$$

Where n is the number of pair X and Y , x_i is the i -th data of X and y_i is the i -th data of Y .

The third important feature was a spatial plot where we checked the sampling coordinates of the chosen area (**Figure 6**). This figure gave a number of the pest at each sample point. Based on these data the automated early warning system generated a distribution of the number of a pest at any site on the observed area (**Figure 7**). The colours represent the pest infestation levels. Therefore, the spatial plot used for identifying high-risk areas, while the spatial plot used for identifying high-risk areas from the pest outbreaks [7, 9].

Sampling Coordinates Plot

Periode	10-2015
Site	SD11
Afdeling	OG
Blok	003
Jenis Deteksi	Rutin
Jenis Ulat	Ulat Api
Tanggal Pengamatan	23 Oktober 2015

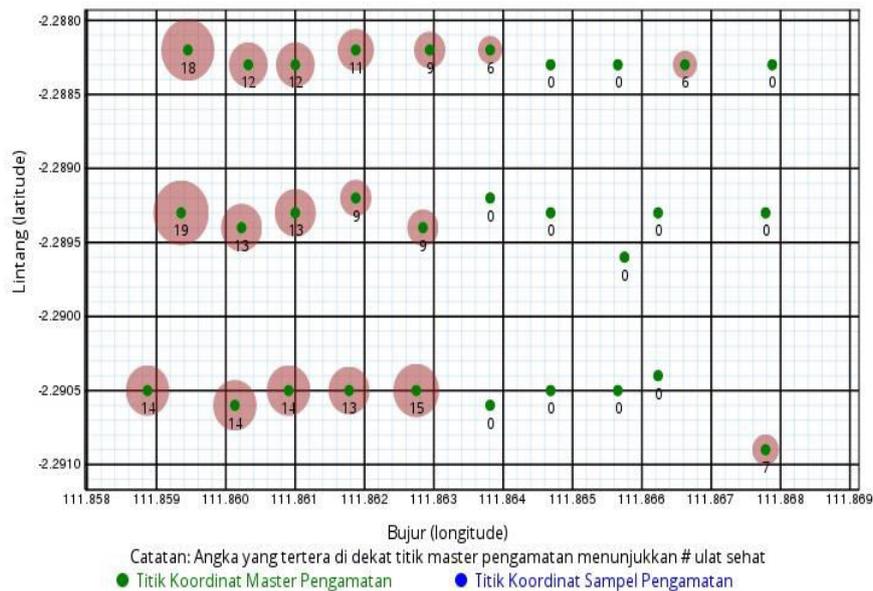


Figure 6. Sampling coordinates.

In the spatial analysis, we define $Y_{t,j}$ as the count at time t at the location j . In our case, there were about 30 sample locations and the following joint distribution density counted as function:

$$c(u_1, u_2, \dots, u_{30}) = \frac{e^{-z^T(\Sigma^{-1}-I)z}}{\sqrt{|\Sigma|}},$$

where $u_j = F(y_{t,j})$, $Z = (\Phi^{-1}(u_1), \Phi^{-1}(u_2), \dots, \Phi^{-1}(u_{30}))^T$, Σ is the kernel matrix, $|\Sigma|$ is the determinant of the matrix Σ , and Φ^{-1} is the inverse cumulative distribution function of a standard normal. Based on the above joint distribution, the spread of the pest given in the spatial plot is predicted by a conditional probability [4].

4. Conclusions

The impacts of EWS automation are to facilitate observers of pest organisms in the oil palm plantations to fill sheets of student manual paper form softcopy that is stored and documented in the company's server; to inform direct field observation data on the same day (h+0), to alert decision-makers and staff *via* smartphone and email in case of pest attacks in moderate and severe categories, and to follow up controlling of plant-disturbing organisms immediately.

Spatial Plot

Periode 10-2015
 Site SD11
 Afdeling OG
 Blok 003
 Jenis Deteksi Rutin
 Jenis Ulat Ulat Api
 Tanggal Pengamatan 23 Oktober 2015

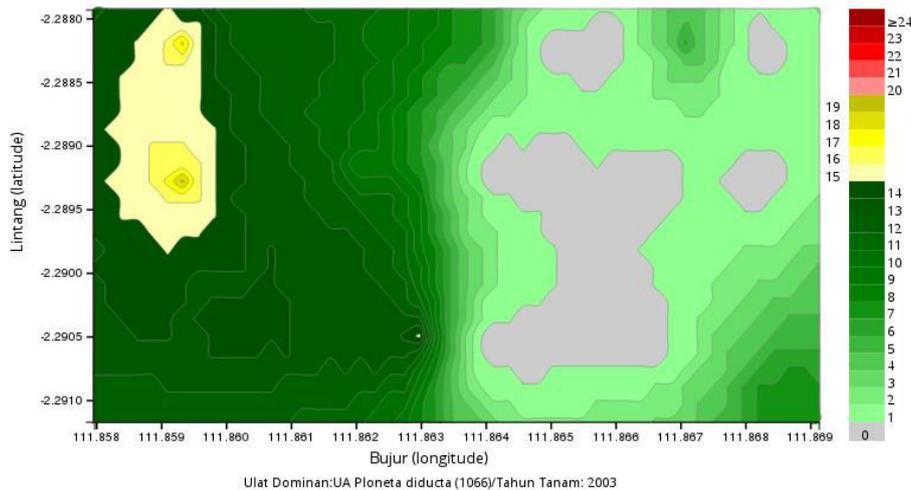


Figure 7. Spatial plot of the distribution of pest.

5. References

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