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Spatial and Hotspots Analysis of Basal Stem Rot Disease in Oil Palm Plantations: An analysis on peat soil

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ABSTRACT

The analysis of plant disease, especially in spatial and temporal terms is very complex process but with the advancement in computer technology, the task has been simplified to large extent. Further, the application of GIS in plant disease analysis is becoming more popular, precise and advanced day by day. GIS helps plant disease analysis in many ways. The primary use is to understand where disease is occurring and based on that preventive measure can be taken. Various analyses can be performed in GIS environment and maps can be derived to benefit a farmer for an effective and comprehensive management of plant disease. For this study, Basal Stem Rot (BSR) disease in oil palm plantation was analyzed. BSR, one of the lethal diseases of oil palm is caused by *ganoderma boninense.* The disease can kill up to 80% of the stand by the time when the palms are halfway through their normal economic life span. In the present study, the choropleth map, then the interpolated density approach followed by statistical technique shows the various steps to move from overall scenario of disease to pin pointing the disease incident location or hotspot analysis. The study resolves that the hotspots generated by choropleth and density map can be refined and more precisely located with the help of spatial statistical approach. The data acquired from these hotspots can be utilized for the study of advanced analysis such as disease distribution pattern.

Keywords: Basal stem rot (BSR); Spatial Analysis; Hotspots Analysis; GIS

I. INTRODUCTION

Currently, Malaysia is the world's largest exporter of palm oil and become the world's leading palm oil producer, with 14.9 million tons of oil palm per year respectively [1]. However, a deadly disease called Basal Stem Rot (BSR), devastate thousands of hectares of plantings in Malaysia and Indonesia [2]. The BSR disease, which usually affects matured palms, is caused by a type of shelf or bracket fungus, *Ganoderma* and is lethal and incurable though it has been identified more than fifty years ago. It has been found to infect oil palms as early as 12 to 24 months after planting, with increased incidence on 4 to 5 years old palms, particularly in replanted areas [3], or areas under planted with coconut palm trees [4]. The disease is presently the most prevalent and devastating disease in oil palm cultivation, especially in mature palm areas in Malaysia [5]. BSR can kill up to 80% of the stand by the time when the palms are halfway through their normal economic life span [6].

Until today, limited studies has been done to investigate the spatial patterns of BSR and how BSR is distributed through out the area of plantation. Such information is needed for fully understand disease dynamics, develop more accurate sampling plants better assesses crop loss in relation in relation to disease intensity and design and analyze experiments more efficiently. For these reasons, there is a need for an effective and comprehensive BSR management plan for the area of oil palm plantation.

The present paper is the attempt to apply Geographical Information System (GIS) to investigate the behavior of BSR in oil palm plantation, especially for peat soil type of plantation. The main objective of this study was to characterize the spatial variability of BSR in oil palm plantation and to determine where BSR disease hotspots exist in order to gain information about the underlying mechanism that drive BSR distribution.

II. MATERIALS AND METHODOLOGY

In this enquiry, the distribution of BSR in peat soil plantation is evaluated. The methodology adopted can be described in the following step:

Data design: The database consisted of several data layers like regional map, plantation map, and palm tree map is used for the purpose of this study. Data design with BSR attributes was generated in a single Microsoft Access database. These data were geocoded and integrated with blocks that representing the different planting density boundary unit. This produced the choropleth maps showing overall BSR incidence count and other attribute specific query in blocks. The map is layered and analyzed using the ArcMap of ArcGIS software.

Hotspots analysis: Spatial incidence data obtained from the geocoded dataset were used to generate hotspots through spatial analyst. Hotspot analysis was carried out to identify and investigate areas of high disease density in oil palm plantation. This was performed using kernel density estimation interpolation technique. Kernel estimation is a technique, used to generalize incident locations to the entire study area. Kernel density estimation is an interpolation that is appropriate for individual point locations [7]. According to Levine [7] the kernel estimate is a better 'hotspot' identifier than the cluster analysis. Kernel density estimation is a useful method as it helps to precisely identify the location, spatial extent and intensity of BSR disease hotspots. The underlying density distribution is estimated by summing the individual kernel functions at all locations to produce a smooth cumulative density function. Hotspots analysis is useful, because it can help in further investigation as why BSR disease is concentrated in particular region.

Geostatistical analysis: A spatial autocorrelation analysis was performed on the field data. The empirical variogram provides a description of how data are correlated with distance or in other word it is a measure of the degree of spatial dependence between samples. The magnitude of the semi-variance between points depends on the distance between them. A smaller distance yields a smaller semi-variance and a larger distance results in larger one [8]. The semi-variogram function (Fig. 1), *γ(h)*, is defined as half the average squared difference between points separated by a distance *h* [9] and is described as:

$$\gamma(h) = \frac{1}{2|N(h)|}\sum_{N(h)}(Z_i - Z_j)^2$$

where *N(h)* is the number of sample pairs at each distance interval h, and z_i and z_j are data values at spatial locations i and j, respectively. The letter *h* represents a distance measure with magnitude only but when direction also considered, it becomes a vector h [9]. A mathematical equation of the semivariogram to express the spatial dependence among samples to allow estimation of values for unsampled location. For properties that are spatially dependent, the increment $(Z_i - Z_j)$ is expected to increase with distance, up to some distance beyond which it stabilizes at a sill value $(C_0 + C)$, and is numerically almost equal to the variance of the data. This distance is called the range and represents the radius of a circle within which the observations are correlated. The intercept to *γ(h)* axis is called nugget effect (C_0), and represents the variability at distances smaller than the minimum sampling distance.

In practice, the direction effect was considered by computing experimental variograms according to different directions of the h vector. The resulting graphs were compared, and no significant differences indicate that the field plot may be considered isotropic. In this study only isotropic models were considered. The spatial structure of the data is determined by fitting a mathematical model to the experimental semivariogram.

III. STUDY AREA

The plantation is situated at Teluk Intan (3.49^{o}N, 101.06^{o}S) and is managed by MPOB (Malaysian Palm Oil Board). The total experiment area is about 10.88 ha. The palms were planted in August 1985 using a hole-in-hole planting method. Previously the area was covered by jungle. The study area is flat, receives a moderately high and uniformly distributed rainfall and has a high soil water table. The annual rainfall at the site varied from 1696 to 2404 mm with the driest month being July and the wettest, November [6].

The soil is characterized a very deep (above 3 metres) peat, comprised of heterogeneous mixture of more or less decomposed plant (humus) material that has accumulated in a water-saturated environment and in the absence of oxygen [6].

Among the important inherent characteristics of the Malaysia peat land is the presence of a dense mass of woody materials, usually water-logged in its natural state, shrinkage and subsidence upon drainage, irreversible drying if excessively drained, extreme acidity and low fertility status [4]. Its structure ranges from more or less decomposed plant remains to a fine amorphic, colloidal mass [10]. The peat medium is a structureless material that has a very low bulk density, low in nutrients and low in pH level [11]. The site was previously a secondary peat forest.

IV. FIELD DATA COLLECTION

Information on BSR disease incidences was obtained from Malaysia Palm Oil Board (MPOB) who is conducting a comprehensive monitoring program since the palms was planted in August 1985. In this study BSR disease incidences in 2005 were studied. The trial was laid out on block 4B1 of MPOB Research Station area.

Three main plots of palm oil densities were created: (1) Plot A (120 palms per hectares); (2) Plot B (160 palms per hectares); and (3) Plot C (200 palms per hectares). Palms were planted with a distance of 9.8 m x 9.8 m x 9.8 m, 8.5 m x 8.5 m x 8.5 m and 7.6 m x 7.6 m x 7.6 m for each tree respectively. The three palm oil densities represent a reasonable range that could be used commercially. The palms were arranged in an equi-triangular planting.

The studied data was collected in 2005. Census was carried out in August where oil palms were visually recorded into two categories with BSR or without BSR disease (healthy). The distribution of the BSR disease incidences on block 4B1 then were mapped using ArcMap of ArcGIS 9.2 (ESRI). Geographic locations of each palm are collected using GPS receiver. The GPS is a highly accurate satellite based radio navigation system providing three-dimensional positioning, velocity, and time information.

V. EXPERIMENTAL RESULTS AND DISCUSSION

A. Choropleth BSR incidences map

Choropleths map have been a very popular way to representing the attribute data. This type of map has become the standard way of representing area value data on paper. Choropleth map of blocks showing the overall BSR disease an incidence was generated (Figure 1).

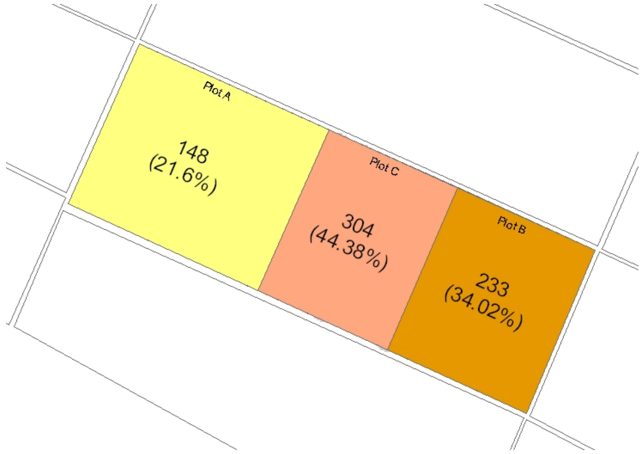

Figure 1. Choropleth map showing BSR incidences count and percentage

Choropleth map result showing that BSR in plot C scored the highest incidences with 304 counts (44.38%), followed by plot B with 233 counts (34.02%), and the plot C with 120 palms per hectare recorded the lowest BSR incidences with 148 counts which representing 21.6% of overall incidences. Choropleth result shows that higher planting density will result higher in BSR disease incidences.

B. Hotspots Analysis

Location of BSR data is the most important of all types of information that is presented on a map. The point interpolation techniques and spatial statistical analysis technique can be performed once the incidence of BSR is geocoded. Prior to the hotspot analysis, all the BSR disease incidences were geocoded and integrated with plots that representing the different planting density boundary unit. Data design with BSR attributes was generated in a single Microsoft Access database and analyzed using ArcGIS software. Figure 2 shows the geocoded data of BSR disease in 4B1.

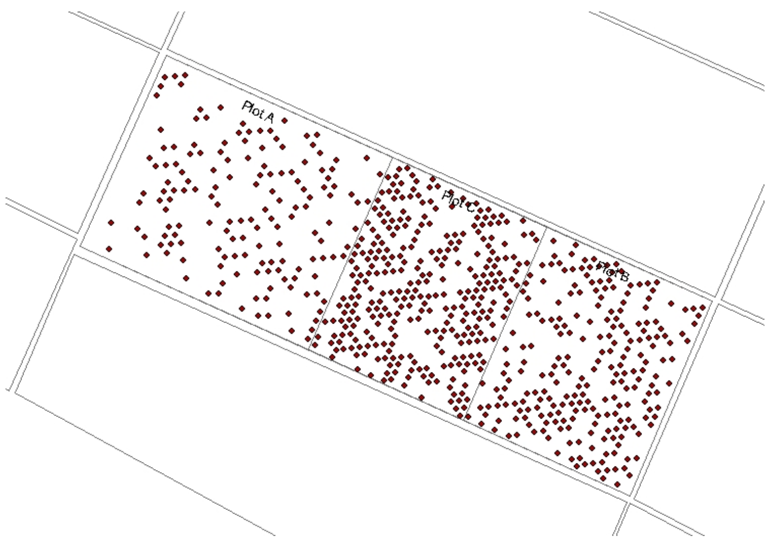

Figure 2. Map showing BSR disease incidences

The dark color area in figure 3 is the hotspot identified with maximum BSR disease density. Hence, with the help of BSR density map we are able to target specific area within plot showing highest incidence. Overall picture of BSR density variation within the plots can be known with the help of kernel density map. From the result, we can identify the area the most affected by BSR disease. Hotspot in plot C was found to be greater in size and density compare to other two plots. More than ten hotspots were identified in plot B and C. Whereas hotspot in plot A was found to be fairly consisted in size and density.

Figure 3. Map showing BSR density per square kilometer.

C. Geostatistical analysis

In order to evaluate the spatial dependence, three classes of spatial dependence for BSR disease were calculated based on the ratio of nugget (C_0) to the sill (C_0+C) [12]. If the spatial class ratio was < 25% the variable was considered strongly spatially dependent; if the ratio was > 25% and < 75%, the variable was considered moderately spatially dependent; and if the ratio was >75%, the variable was considered weakly spatially dependent [12]. All the result presented corresponds to the isotropic variogram.

Based on spatial structure produced by semivariogram, the distribution of BSR disease incidence was random in 2005. This means that all palm trees had a same probability of developing the BSR disease. Although the finding shows that the distribution of BSR was random but the result indicates that in higher density plantation, the probability of developing the BSR disease was higher compare to lower density plantation.

Plot	Model	Nugget (C_0)	Sill (C_0+C)	Ratio C_0/(C_0+C) (%)	Range (m)
A	Spherical	0.2	0.21	95.2	35
B	Spherical	0.24	0.255	94.1	60
C	Spherical	0.24	0.26	92.3	65

Table 1. Semivariogram result

Table 1 presents summaries of variogram for the studied area. All the semivariograms were fitted to the spherical model and revealed the average ranges of 35m, 60m and 65m for plot A, B, and C respectively. There was a strong indication that the BSR disease in plot A, B, and C were initially randomly distributed throughout the plantation.

The parameters of semivariograms were fitted according to the model that gave the best coefficient of determination (R^2). These models were then validated through the relation $C_0 /(C_0 + C)$, in which we can see that for this BSR disease, the index values were 95.2%, 94.1%, and 92.3% for plot A, B and C respectively (Table 1). From the result, the spatial autocorrelation found to be relatively weak for all plots. The result shows that the phenomenon being studied is tending towards randomness, with no relation between samples.

VI. CONCLUSION

To summarize, this study demonstrates various methods adopted to identify BSR disease hotspots in order to pin point the incidence locations. In present study, the choropleth map shows the BSR occurrence in a small plot unit. This map provides overall BSR scenario in the area. When extremely precise and detail investigation and study planned, the interpolation and spatial statistical techniques comes in picture.

The semivariogram analysis showed that the BSR disease distribution was random in plot A, B and C. Therefore, based on this analysis we concluded that the distribution of BSR disease was not associated with oil palm density condition. This study also shows that the distribution of the BSR disease incidence is far higher for the plantation field with a higher density of palm trees compared to palm trees that were in lower density plantation. The occurrence of BSR disease is not a function of an infection from tree to tree, but a function of the disease pressure in the area.

The ability to develop good spatial modeling of BSR disease will allow a better planning for actions required to eliminate factors that may cause the development of basal stem rot disease.

The knowledge of spatial pattern of BSR disease is useful for making management decisions, especially for application of site-specific management as in precision agriculture. If a section of the field where the pathogen survives is identified and the pathogen density is quantified, there is no need to apply pesticide on the entire field.

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