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The Influence of Abiotic Factors on the Occurrence of Jackfruit Dieback Disease

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ABSTRACT

The jackfruit (*Artocarpus heterophyllus*) is one of six high-value non-seasonal tropical fruits identified as a target for export fruit products in the Malaysia National Key Economic Area (NKEA) report. It is challenging to sustain the jackfruit crop's productivity and achieve the targets for the growth of premium fruits because of the emergence of plant diseases that can affect yields. This paper discusses the influence of abiotic factors, including landscape and weather, on the occurrence of *Erwinia carotovora* disease. This paper applied Ordinary Least Square (OLS) and hotspot analysis to understand the occurrence of the disease from the landscape and spatial perspective. The findings suggest that the rate of *E. carotovora* in jackfruit trees (based on a percentage of the area affected) is significantly affected by the proximity of the trees to roads, rivers, and irrigation. At the same time, the frequency of *E. carotovora* is substantially dependent on rainfall levels. The Koenker (BP) statistic provides a consistent set of results that explain the relationship between variables that impact the occurrence of dieback jackfruit disease remains the same over the study area. This study helps us understand how specific landscape characteristics and climatic variables influence jackfruit dieback disease. This area of research is

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essential so that the best land management practices can be adapted to prevent future disease occurrences.

Keywords: Abiotic factors, *Erwinia carotovora*, Koenker statistic, landscape management, spatial analysis, tropical agricultural

INTRODUCTION

Jackfruit is one of the six high-value non-seasonal tropical fruits identified as a target product in the National Key Economic Area (NKEA) report. According to 2017 data, jackfruit is one of 21 tropical fruits commercially grown in Malaysia (DOSM, 2017). Jackfruit was recorded as having a self-sufficiency level (SSL), with the country producing more than 100% (111.1%) of domestic consumer needs: over 30,000 tonnes per year (Durai, 2021; Rozhan, 2017). Pahang, Negeri Sembilan, Sabah and Johor are the states that supply the most jackfruit for Malaysian consumption and export to international markets (MAFI, 2021).

Plant diseases must be investigated to sustain jackfruit productivity and achieve the national gross per capita of premium fruits, and relevant strategies must be implemented to meet national targets. Despite the emergence of several plant pest and disease models in the past decades, pests, weeds, and diseases continue to impact agricultural industries worldwide (Jeger et al., 2018; Zulperi et al., 2017).

BACKGROUND

Jackfruit

Jackfruit (*Artocarpus heterophyllus*) is a member of the Moraceae family. The plant genus, Artocarpus, comprises 50 tropical species native to the Asia-Pacific region. It is a prevalent tree in home orchards where people often grow fruits and vegetables for personal consumption (Elevitch & Manner, 2006).

Many believe that the jackfruit originated from India’s Western Ghats Mountain range; some studies reported finding trees in the primary forest away from human habitation. Meanwhile, another study suggests that it originated in Malaysia because of the broad diversity of jackfruit cultivars (Dickinson et al., 2020; Ranasinghe et al., 2019; Khan et al., 2010). It then spread to countries such as Australia, Brazil, and Indonesia (Ismail & Kaur, 2013). Elevitch and Manner (2006) describe how jackfruit grows well in the equatorial to subtropical maritime climates of the Indian and Pacific oceans and favours tropical moist to semi-dry forests.

Since 2001, several jackfruit clones have been grown commercially (FAMA, 2001), hence the variety of jackfruits available in Malaysia like Mastura, Mantin, Tekam Yellow, Golden Fruit, J29, N.S.1, CJ1, CJ3 and CJ6 (DOA, 2017). These clones perform well in the Malaysian market because they are small and sweet with fleshy, smooth pulp and an attractive colour (Ismail & Kaur, 2013).

According to Elevitch and Manner (2006), jackfruit may withstand other soil types, such as shallow limestone, sand, and rocky substrates but does best in well-drained, deep soils of moderate fertility. The tree does not tolerate poor drainage or water stagnation. The tree will not bear fruit or perish if its roots come into contact with still water. The tree can grow in soils with light and medium textures (sands, sandy loams, loams, and sandy clay loams). It needs free drainage and can grow in neutral to slightly acidic soils (pH 5.0–7.5). Jackfruit may grow in infertile, shallow, and somewhat saline soils. It can also grow in rocky, laterite, and high-pH limestone soils. The jackfruit can survive three to four months of dryness but thrives with consistent and constant soil moisture (Blom-Zandstra et al., 2017).

Jackfruit Disease

The jackfruit crop is susceptible to various diseases caused by fungal and bacterial infections affecting the leaves, branches, twigs, stems, and roots (Haq, 2006; Sabtu et al., 2019). According to Borines et al. (2014), jackfruit disease incidence tends to increase during the wet season, especially in areas prone to flooding or with poor drainage. Diagnosing the cause of jackfruit decline is crucial to assist in developing disease management strategies and the industry's survival.

Several diseases that infect jackfruit are dieback (caused by *Botryodiplodia theobromae*), fruit rot (*Rhizopus artocarpi* and *Rhizopus stolonifer*), and leaf spot (caused by *Phyllosticta artocarina*), and pink disease (caused by *Botryobasidium salmonicolor* and *Corticium salmonicolor*) (Love & Paull, 2011). Other diseases such as charcoal rot (*Ustilana zonata*), collar rot (*Rosellinia arcuata*), grey blight (*Pestalotia elasticola*), and rust (*Uredo artocarpi*) also occur on jackfruit crops in some regions.

In Malaysia, the most common disease affecting the jackfruit crop is wilt/dieback disease caused by a bacterial pathogen, Erwinia carotovora, pink disease caused by *Erythricium salmonicolor* and fruit rot disease caused by *Phytophthora palmivora* (DOA Sarawak, 2006).

Jackfruit dieback disease is associated with different causal pathogens, *Lasiodiplodia theobromae* and *Erwinia coratovora*. *Lasiodiplodia theobromae* is a fungus capable of infecting growing shoots, causing discolouration of the bark and, in severe cases, causing the death of the jackfruit tree (Haq, 2006; Sabtu et al., 2019). However, the bacteria *E. carotovora* is also associated with dieback disease, which infects most *Artocarpus* species (Love & Paull, 2011), and this causal pathogen is the focus of this study.

Erwinia carotovora is a phytopathogenic enterobacterium that causes soft rot, blackleg, or stem rot on many crops (De Boer & Kelman, 2001). The bacterium *E. carotovora* causes dieback resulting in leaf yellowing and gummy exudates from the stems and branches (Abhijit et al., 2012; Borines et al., 2014; Sangchote et al., 2003). White latex can be seen oozing out of the dark stains on the branches. A chocolate patch is found in the bottom when infected skin is removed. This necrotic area eventually blackens and can develop into large cavities that resemble those caused by the weevil borer. The disease spreads between branches and causes the whole tree to wilt. The fruit infected trees produce is relatively tiny and ripens prematurely compared to uninfected fruits (DOA Sarawak, 2006). Fruits can also become infected with this pathogen which insect transmits. The pathogen may infect young fruits, resulting in black, rotten, shrunken and sometimes withered fruit. Symptoms can appear before the fruit is harvested and on fruits in transit or storage. If not managed properly, these diseases can potentially damage fruit production severely.

According to Bhat et al. (2010), *E. carotovora* is a gram-negative bacterium, rod-shaped, facultatively anaerobic, catalase positive, oxidase negative and urease harmful bacteria. The optimum temperature for *E. carotovora* growth is 30°C. According to Kumar and Ragupathy (2012), a temperature range of 25°C–30°C with low relative humidity (80–85%) and the presence of susceptible hosts favours dieback disease. It allows it to proliferate (Kumar & Ragupathy, 2012).

A study by Nadarasah and Stavrinides (2011) stated that insects are one of the intermediaries that spread plant pathogens. According to Elevitch and Manner (2006), boring insects are the major pests of jackfruit in southwestern and southern Asia; these include *Batocera rufomaculata*, *Indarbela tetraonids*, *Margaronia caecalis*, and *Ochyromera artocarpio* (Rajkumar et al., 2018; Ibrahim et al., 2022; Khan et al., 2021; Khan & Khan, 2020; Sabtu et al., 2019;). According to a survey conducted between 2013 and 2016, fifty-one insect pests were found on jackfruit in the south Indian states of Karnataka, Kerala and Tamilnadu (Kallekkattil et al., 2020). Shoot-boring caterpillar (*Diaphania caesalis*) is the major pest (Elevitch & Manner, 2006; Gullan & Cranston, 2014), including mealybugs (*Nipaecoccus viridis*, *Pseudococcus corymbatus*, and *Ferrisia virgata*), spittlebug (*Cosmoscarta relata*), and jack scale (*Ceroplastes rubina*). The larva of *D. caesalis* is a voracious feeder that causes severe fruit damage. Khan and Islam (2004) reported that *D. caesalis* caused 27.44% of damage in jackfruit plantations in Bangladesh.

METHODOLOGY

The methodology applied in this study is shown in Figure 1, as this study used climatic and landscape data (Table 1). The Malaysian Meteorological Department obtained climatic data from 2011–2017. The *E. carotovora* jackfruit disease incidence data were collected from the Plant Biosecurity Division of Johor. River, irrigation, and rainfall data were obtained from the Department of Irrigation, and Drainage of Johor, and elevation data from TanDEM sentinel was 12 meters. All data were initially in different coordinate systems, such as World

Geodetic System 1984 (WGS 84) and Cassini Soldner Johor map projection. Then, the data were transformed into Malayan Rectified Skew Orthomorphic (MRSO) Kertau map projection. Eight variables were extracted from these data to analyse the relationship using Ordinary Least Square (OLS) analysis. Jackfruit disease incidence records (location), road, river, and irrigation are vector shaped. The elevation data was converted from raster to vector format, and then 20-meter contour lines were created to obtain the elevation value for jackfruit disease incidence.

The spatial database consists of all data collected in the second stage. The data were divided into either spatial or attribute data. Spatial data describes a location on the earth's surface, whereas attribute data describes a spatial object in the database. Roads, water bodies and elevation data were included in the spatial data, while the others were included in attribute data.

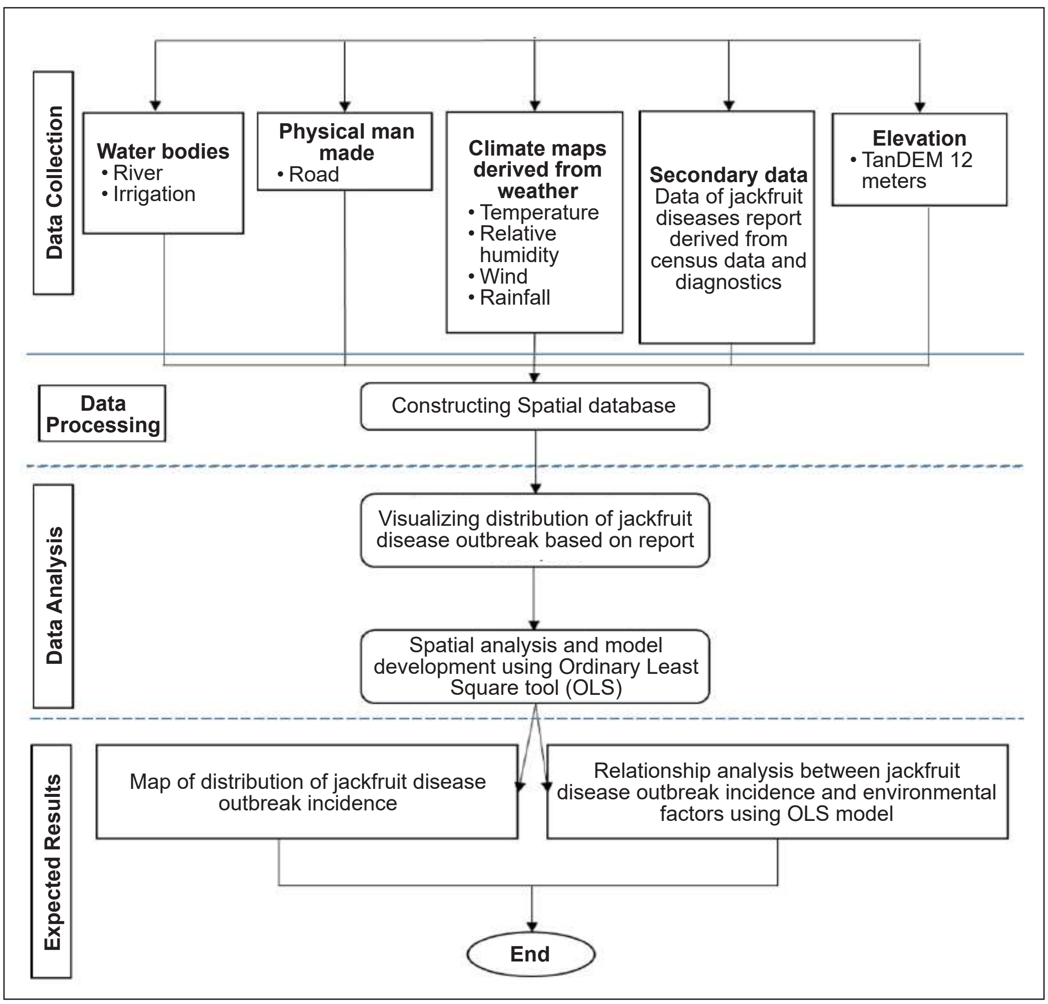

Figure 1. Methodology flowchart

Table 1
Description of each variable

Variables	Data Descriptions
Jackfruit diseases incidence records (in percentage) **Jackfruit diseases frequency occurrence (in quantity)**	Jackfruit diseases report is derived from census and diagnostics data from the year 2011 until 2017 (Source: Plant Biosecurity Division of Johor)
Maximum temperature (unit degree Celsius)	The maximum temperature in every district in Johor State from the year 2011 until 2017 (Source: Malaysian Meteorological Department)
Relative humidity (unit %)	Daily relative humidity in every district in Johor State from the year 2011 until 2017 (Source: Malaysian Meteorological Department)
Maximum wind (unit meter per second)	Daily mean wind speed at every district in Johor state from the year 2011 until 2017 (Source: Malaysian Meteorological Department)
Rainfall (unit millimetre)	Daily rainfall in every district in Johor State from the year 2011 until 2017 (Source: Department of Irrigation and Drainage of Johor State)
Road (unit meter)	Road features for the entire Johor (Source: Malaysian Public Works Department)
River (unit meter)	River features for the entire Johor (Source: Department of Irrigation and Drainage of Johor State)
Irrigation (unit meter)	Irrigation features for the entire Johor (Source: Department of Irrigation and Drainage of Johor State)
Elevation (unit meter)	Elevation data is extracted from TanDEM 12 meters (Source: TanDEM)

The maximum temperature, relative humidity and wind data were gathered and displayed in Shapefile format according to their coordinates and using the "Add XY Data" function in ArcGIS 10.3.

Moran's I spatial autocorrelation was performed on each explanatory variable to understand the distribution of data acquired from the sources (Table 1). Moran's tool determines whether the spatial pattern is random or clustered. Statistically significant clustering under or over predictions indicates a variable is missing from the model (misspecification) (ESRI, 2016a). Hence, the OLS model that mis-specifies or provides spatially random results is not deemed reliable. Also, it is considered unreliable if the residuals are statistically significant and autocorrelated (ESRI, 2016a). Data distribution must be random, and the residual is not statistically significant or autocorrelated to meet the requirement to conduct OLS regression.

This study's initial distance to road and elevation data shows clustered spatial autocorrelation. Random spatial autocorrelation is preferred in OLS analysis, or the output analysis cannot be trusted. From a scatter plot matrix graph, the data distribution of the dataset was non-normal. Moreover, each variable showed a few outliers. Hence, the non-normal distribution data were transformed into a natural logarithm (ln) for all datasets, including maximum temperature, relative humidity, wind, rainfall, road distance, river, irrigation, and irrigation elevation. SPSS software was used to transform the dataset into natural log distribution. Outliers were also identified through a box-plot graph and were removed.

Next, data were processed to generate new attributes by calculating the distance of the disease records to the tested variables—the Near tool (in ArcGIS software) calculated the distance between input features. The distance calculation depends on the geometry type and coordinates system (ESRI, 2016c). The input feature is the record (point location) of *E*. *carotovora* jackfruit disease to the nearest road, irrigation, river, and elevation. The *E*. *carotovora* jackfruit disease data was in point feature while other relative features were in line. The output from this analysis was the distance value (in meters) added as a new column (namely, NEAR_DIST) in the *E*. *carotovora* jackfruit disease attribute table.

The distance was calculated based on these basic rules below (ESRI, 2016d):

1. The distance between two points is the straight line connecting the points.
2. The distance from a point to a line is perpendicular or the closest vertex.
3. Segment vertices determine the distance between polylines.

The variable's distance to roads, rivers and irrigation layers was calculated by measuring their proximity to *E*. *carotovora* jackfruit disease occurrences.

Hotspot Analysis

This study used a Kernal density tool to map the hotspot of disease occurrence. The tool calculates the density of input features within a neighbourhood. Regarding ESRI (2016b), it is the magnitude of each sample location (line or point) over a surface. A circular search area is applied for a density map to determine the distance to search for sample locations or whether to spread the values around each location and calculate a density value. Density surfaces show the concentration of point or line features.

For mapping the density of *E*. *carotovora* jackfruit disease, the hotspot analysis was carried out using ArcGIS software. The distribution of the disease was weighted based on the number of incidences.

Ordinary Least Square (OLS) Linear Regression

Ordinary Least Square (OLS) linear regression is a statistical method for estimation and prediction. According to ESRI (2016a), OLS linear regression estimates the unknown parameters in a linear regression model. The technique minimises the sum of squared vertical distances between observed answers in the dataset and the expected responses, utilising a linear approximation. ESRI (2016a) also state that the OLS linear regression in ArcGIS can predict and model the relationship between a dependent variable and a set of explanatory variables.

The OLS regression model analysed the relationship between *E. carotovora* and the independent variables (i.e., maximum temperature, relative humidity, rainfall, and wind speed), along with topographical surface features such as distance to the river and road and irrigation. All variables were analysed with the dependent variable and tested to identify the most influential variable concerning disease occurrence. OLS assesses the overall relationship between the dependent and independent variables. The dependent and independent factors analysed in this study are displayed in Table 2.

Table 2
List of dependent and independent variables used in the OLS tool

Type of Variable	Parameters
Dependent	1. Affected area per hectares (Severity of *E. carotovora* jackfruit disease occurrence) (in percentage) *2. E. carotovora* jackfruit disease occurrence (in frequency)
Explanatory (Independent Variables)	1. Maximum Temperature (annual average) 2. Relative Humidity (yearly average) 3. Mean Wind Speed (yearly average) 4. Distance to Road 5. Distance to River 6. Distance to Irrigation 7. Elevation (20m contour) 8. Rainfall (yearly average)

The modified R^2, variance inflation factor (VIF), and coefficient values are shown in the regression tool's output to illustrate the model's performance, which comprises the tested dependent and independent variables. Several R^2 and adjusted R^2 values measure the model's performance. Adjusted R^2 always has a lower value than multiple R^2 since it indicates model complexity, according to ESRI (2016a). Because it directly relates to the data, the adjusted R^2 is a more reliable performance indicator than many other R^2. The range of potential values is 0.0 to 1.0. Esri (2016a) recommended removing variables with VIFs greater than 7.5 from the model even though the VIF assesses redundancy among variables.

The joint-F-statistic and conventional Wald statistic values were used to determine the statistical significance of the entire model. The joint-F-statistic is reliable only when the Koenker (BP) statistic is not statistically significant (ESRI, 2016c). The Koenker (BP) statistic determines whether the model's explanatory variables are consistently related to the dependent variable regarding the available data and spatial location (ESRI, 2016c). In the studied area, the spatial process operates uniformly if the model is compatible with spatial distance.

According to ESRI (2016a), probability (p-values) reveals the statistical significance of the regression model and if the theory or common sense strongly suggests a relationship with the dependent variable. Explanatory variables must not be redundant with other explanatory factors in the model and must predominantly be linear. The p-value in a statistically significant model must be less than 0.05. The model is not statistically significant, and the model relationship is inconsistent if the p-value is higher than 0.05. The relationship variation between the predicted value and each explanatory variable remains constant if the model is consistent in the data space. Due to volatile output characteristics brought on by local multicollinearity, a regression model with statistically significant stationary values is not recommended for geographically weighted regression (GWR) research.

RESULTS AND DISCUSSION

The Mapping of *Erwinia carotovora* Jackfruit Disease

This study analyses the abiotic factors that influence *E. carotovora* jackfruit disease occurrence. A total of 162 reported *E. carotovora* jackfruit disease incidences were reported in Johor between 2011 and 2017. Figure 2 shows the temporal data of *Erwinia. carotovora* jackfruit disease occurrence for the same period. 2013 shows the highest number of instances, with 44 cases recorded by the Plant Biosecurity Division of Johor. The next highest years were 2012 and 2015, with 43 and 33 cases, respectively. The lowest cases were recorded in 2017 and 2014, with five and four, respectively. Figure 3 shows the distribution of *E. carotovora* jackfruit disease in Johor state overlaid with land use and cover.

The Near tool was used for proximity analysis, summarising each explanatory variable's lowest and maximum values. This data could benefit farmers that plant jackfruit because it can be used to reduce disease occurrences. The summary of minimum and maximum physical explanatory variables is shown in Table 3, and the visualisation of the map is shown in Figure 4.

We can roughly estimate that the crop locations that might be free from bacterial dieback disease infections are approximately within a radius of 6 km from nearby roads, 8 km from nearby rivers, 15 km from irrigation, and at an elevation of 116 meters above sea level (Table 3).

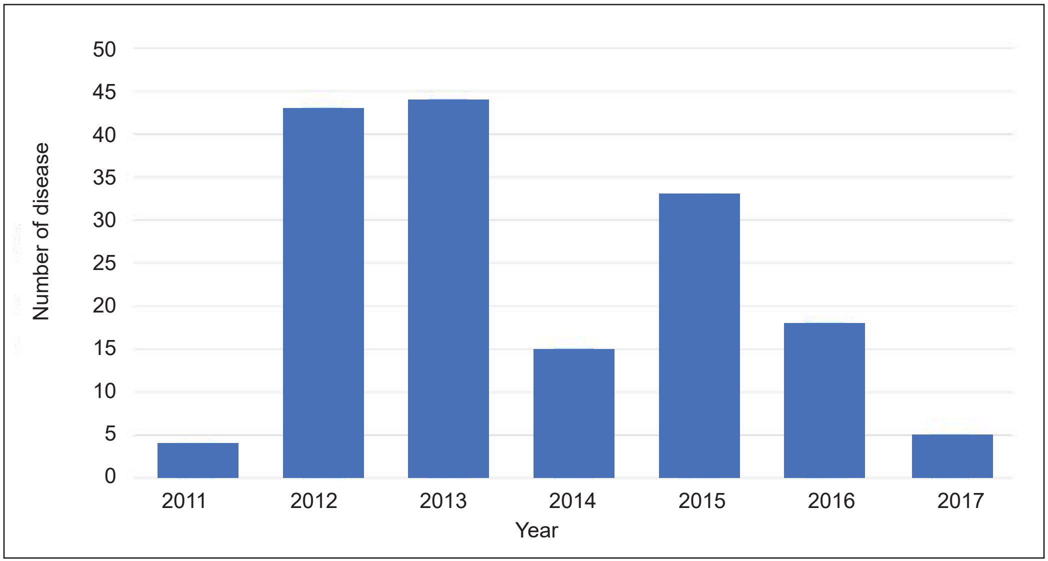

Figure 2. E. carotovora jackfruit disease occurrences from 2011 to 2017

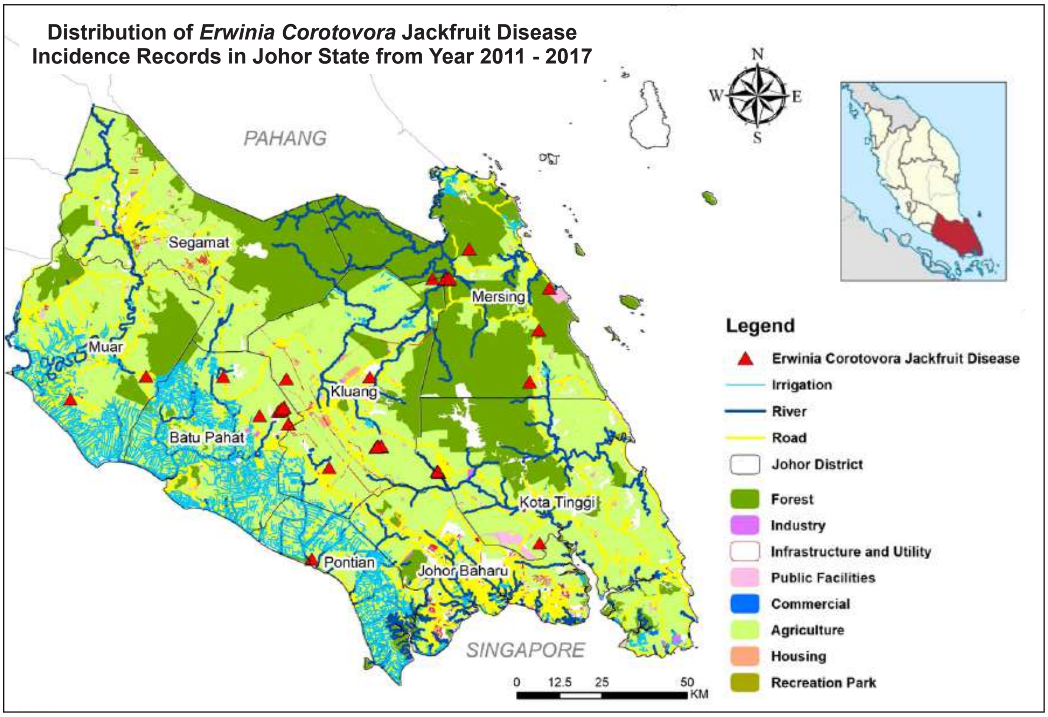

Figure 3. Distribution of *E. carotovora* jackfruit disease incidences in Johor State

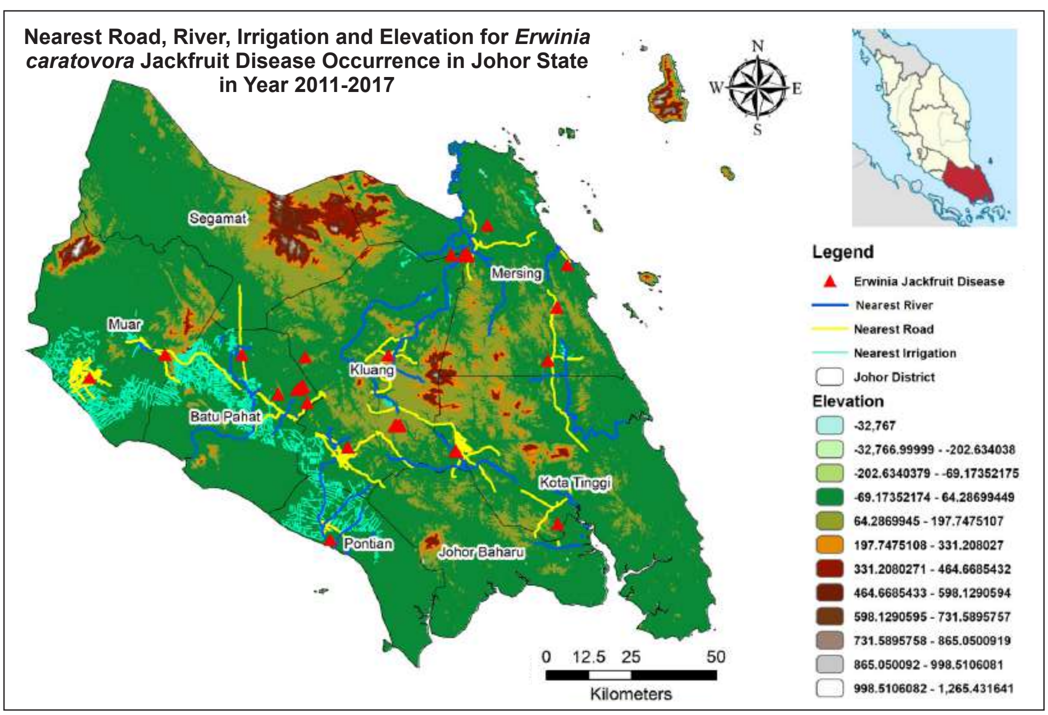

Figure 4. Topographic map for E. carotovora jackfruit disease occurrence

The Kernel density tool results show the hotspot for *E. carotovora* jackfruit disease in Figure 5. The gradient colour (green to red) from the figure shows the density of *E. carotovora* jackfruit disease distribution. Red cells have more records surrounding them than green cells. The higher the Kernel density value, the greater the concentration of disease incidence. In conclusion, the hotspot for *E. carotovora* jackfruit disease occurs in Ayer Hitam in Batu Pahat, Bukit Lawing in Kluang, and Felda Nitar 2 in Mersing.

Table 3
Summary of minimum and maximum physical explanatory variables

Variables	Min Value (Meters)	Max Value (Meters)
Road	5.59	5576.17
River	498.03	7637.73
Irrigation	224.79	14819.61
Elevation	10.73	115.42

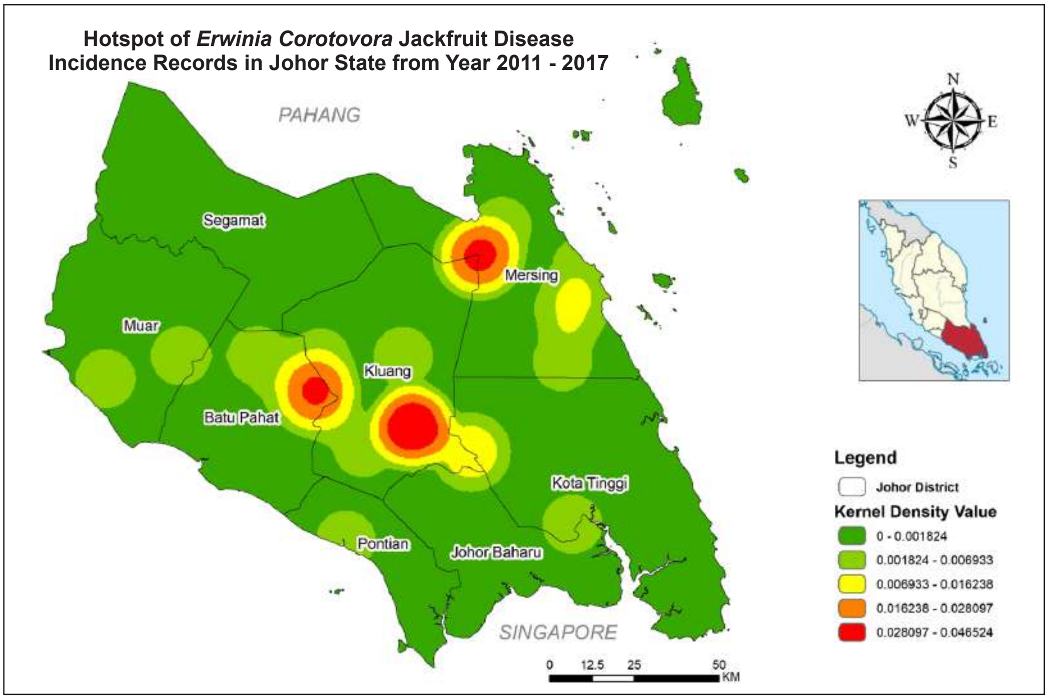

Figure 5. Hotspot area of *E. carotovora*

The Dominant Factors

Eight abiotic factors investigated their relationships with the dieback disease occurrence in this study (Table 2). According to OLS regression (Table 4), this model has a multiple R^2 of 0.788745 and an adjusted R^2 of 0.619741. As a result, this model can

Table 4
OLS diagnostics results

Multiple R-Squared 0.788745	Adjusted R-Squared 0.619741
Joint F-Statistic 4.667013	p-value: 0.013233*
Koenker (BP) Statistic 2.441167	p-value: 0.964418

account for about 61% of the variation in the explanatory variables in the entire jackfruit disease-affected area. Alshibly (2018) claims that the better the model matches the data, the greater the R^2.

Table 5 shows the first model tested in this study (i.e., the size of the area affected by *E. carotovora* jackfruit disease). From the model, the size of the affected area has a significant relationship with the distance to roads, rivers, and irrigation. The p-value of roads, rivers, and irrigation is less than 0.05; hence these variables are significant. Whereas Table 6 shows different dependent variables (i.e., frequency of disease incidence) and their OLS regression results where the rainfall value closely influences the frequency of disease occurrence since the p-value is significant ($p < 0.05$).

The VIF of all explanatory variables (i.e., maximum temperature, humidity, maximum wind, rainfall, river distance, road distance, irrigation distance, and elevation) are jackfruit disease incidence records in Johor state less than 7.5 (Tables 5 and 6). It implies that the explanatory variables are not mutually exclusive. The comparison of disease incidence

Table 5
OLS results of dependent variable: Diseases incidence (as the total percentage of the affected area) versus explanatory variables

Variable	Coefficient (a)	*t*-Statistic	Probability [b]	VIF [c]
Temperature	5.218971	0.822658	0.429871	2.065216
Humidity	3.695793	0.845752	0.417459	1.560448
Wind	1.379807	1.506446	0.162885	2.107248
Rain	0.321554	0.466808	0.650636	1.335430
Road	0.671931	4.582496	0.001013*	2.805546
River	-1.044560	-2.837530	0.017625*	1.511604
Irrigation	-0.920625	-2.551858	0.028763*	2.595937
Elevation	-0.007164	-0.013018	0.989871	2.787380

*Significant at $p < 0.05$

Table 6
OLS results of dependent variable: Diseases incidence (in frequency) versus explanatory variables

Variable	Coefficient (a)	*t*-Statistic	Probability [b]	VIF [c]
Temperature	8.159650	1.587765	0.143433	2.065216
Humidity	7.626628	2.154507	0.056618	1.560448
Wind	1.098949	1.481130	0.169393	2.107248
Rain	-1.677950	3.007075	0.013192*	1.335430
Road	0.035788	0.301297	0.769370	2.805546
River	-0.408323	-1.369275	0.200894	1.511604
Irrigation	0.178177	0.609685	0.555655	2.595937
Elevation	-0.764875	-1.715687	0.116985	2.787380

*Significant at $p < 0.05$

coefficient (a) according to the total percentage of the affected area and frequency versus explanatory variables were shown in Figure 6 to illustrate and explain the data better.

From the coefficient results for the first model, we can remove the variables related to the maximum temperature, humidity, wind, elevation, and rainfall since the probability is insignificant (Table 5). From the table, this study identified that the road distance variable is positively associated with the affected size area of *E. carotovora* jackfruit disease incidence. The bigger affected area is due to the greater distance from the road. In other words, road distance has no significant effect on disease incidence.

While the relationship between river distance and irrigation distance negatively affects incidence rates. Therefore, the association is inversely proportional to the size of the affected area. It aligns with a study by Mgcoyi (2011) which stated that *Erwinia* is commonly found in lakes, rivers, and reservoirs during the summer, late spring, and early autumn. The presence of these microorganisms affected the water quality. This study concludes that the larger affected area may be due to the shorter distance to the water body.

The Koenker (BP) statistic for the regression model is 2.441167, and the p-value is 0.964418, higher than 0.05. This result means the model is not statistically significant; hence the relationship of the explanatory variables is consistent. According to Chang (2008), this consistency ensures that the relationship between variables remains the same in a different area. Hence, performing geographically weighted regression (GWR) was not necessary.

Due to the Koenker (BP), the statistic is not statistically significant, and the F-statistic can be used to determine the overall model significance. The p-value of the joint F-statistic

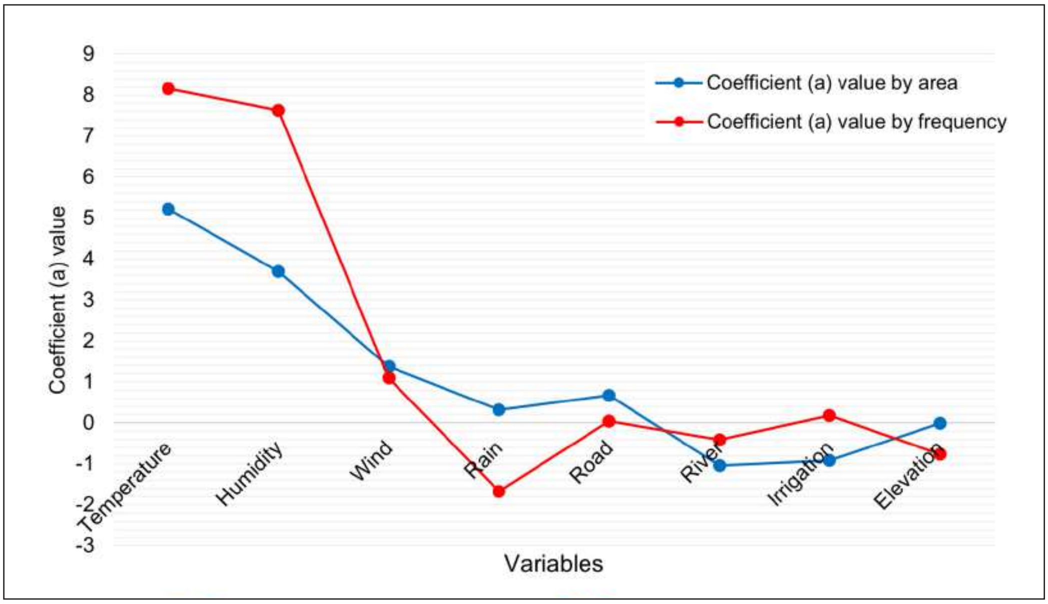

Figure 6. The comparison of the diseases incidence coefficient according to the total percentage of the affected area (blue) and frequency (red) versus explanatory variables

is 0.013233, which means the whole model is statistically significant (Table 4). According to Van Maanen and Xu (2003), rainfall is crucial to disease dispersion. The OLS results show that *E. carotovora* jackfruit disease incidence (based on the frequency of incidents) significantly depends on rainfall, where the p-value is less than 0.05 (Table 6).

CONCLUSION

This paper discusses the impact of abiotic factors that influence the occurrence of *E. carotovora* disease in jackfruit plants. The finding suggests that abiotic factors are influential regarding the presence of the disease. Most related literature frequently associates disease occurrence and severity with abiotic factors. Based on the findings in this research, it is concluded that distance from roads, distance from rivers, and distance from irrigation are the abiotic factors that determine the total percentage area of *E. carotovora* jackfruit disease. However, disease incidence data show that only rainfalls influence jackfruit dieback disease occurrence frequency. The analysis shows that distance from the river and irrigation are inversely proportional to the total percentage area of *E. carotovora* jackfruit disease incidence.

The limitation occurs of this study is the lack of temporal data to indicate the exact date of jackfruit disease occurrence. Furthermore, a lack of detailed climatic data on rainfall in the incidence area hinders the further analysis of the variable. Because of the lack of specific data, the annual average was used to perform the analysis. The model should be validated for future research to ensure reliable relationships in different samples and areas.

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