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Intra-species Space Competition in Cocoa Ecosystem: Invader Ants' Geovisualisation

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ABSTRACT

The Malaysian Cocoa Board (MCB) has conducted numerous research and development activities to ensure the cocoa industry's sustainability. One of the essential aspects is the management of pests and diseases of cocoa. A qualitative study to detect the relationship between presences of biological control agents, Cocoa Black Ant (CBA) against the major pest of cocoa (Cocoa pod borer, CPB) with other ants' intrusion was done with the aid of geospatial mapping and analysis approaches. Other species of ants (ant invades) will affect the availability of CBA in controlling CPB infestation. Thirty months of data collection comprised two different blocks; Blocks 10B and 18A were used as the study area. Analysis of the differences and similarities of other ant's intrusion for each block and Plots was performed to understand the behavior and distribution pattern. Four different methods were introduced; Plot A was augmented with one artificial ant nest for every two cocoa trees, Plot B had one nest on every single cocoa tree, Plot C had two nests on every single cocoa tree, and Plot D without an artificial nest. The study reveals that the highest or lowest CBA populations and distribution could induce a strong, reasonable relationship against other ant types. Plots with artificial ant nests (A, B, and C) showed low intrusion rates with a ratio of 1:1 for Plot B indicated the best result, whereas, Plot without artificial ant nest (Plot D) the highest rate of intrusion during the months and years of observation. The findings in this research provide a new indicator of the ants' species interaction using temporal geospatial-based mapping and analysis within a cocoa plantation ecosystem

Introduction

The cocoa crop is one of the national commodities and plays an essential role in Malaysia's economy. These plants can bear fruit throughout the year to be a source of daily or weekly income for growers. Cocoa, like other plants, also has problems with diseases and pests wherever it is grown. Some pests can reduce not only the yield but also inhibits the growth of trees. In addition to cocoa, pests are also useful insects as parasites, predators, and insect pollinators. In Malaysia, the cocoa pod borer (CPB), *Conopomorpha cramerella Snellen* is a significant cocoa pest today. The CPB attack effects resulted in low quality of cocoa beans. If not controlled, CPB affords yield losses of up to 100% (Saripah, 2012).

Various efforts have been undertaken to control insect pests of cocoa since it was founded attacking cocoa. These include biological control and chemical control. Nowadays, chemical control is a widely practiced method for controlling insect pests. This effectiveness will be increased if coupled with a spraying pesticide frequency shortly before the harvesting stage. However, this technique has a relatively high cost. Besides cost, chemical pesticides with high doses may lead to resistance mechanisms and effects on the environment. Alternative methods such as biological control have yet to be widely used despite the potential to use it properly. One of the natural enemies proven effective in controlling fruit pests is ants known as Cocoa Black Ants (CBA) acted as an effective biological control (Babin, 2010; Saripah, 2010). CBA will eat the larvae of CPB and thus reduce the rate of attacks. However, farmers should always check whether the black ants on a tree are still a lot, especially in the rainy season (Saripah, 2003; Saripah, 2014).

In agriculture application, GIS data, tools, and techniques are beneficial for predicting the area and production of

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agricultural commodities, mapping agriculture land resource potential, and predicting the spread of pests and diseases of plants such as CPB (Adnan *et al.*, 2018; Ayorinde *et al.*, 2014; De Caires *et al.*, 2015). GIS technique can be used on a large scale (detailed) incorporated high-resolution input data, hence producing an accurate result (product). Furthermore, GIS can also be based on a small scale with low-resolution input data and produce lower accuracy in a wide-area mapping. In this paper, the two objectives of the study are i) to generate the other ants' intrusion distribution map for four Plots within two blocks (i.e., 18A and 10B) based on monthly and yearly conditions and ii) to assess the qualitative relationship between CBA augmented nest and other ant's intrusion category.

Materials and Methods

The methods involve three stages: data collection, data conversion, processing in GIS software, data analysis, and findings. Thirty months (with biweekly data collecting activities) database of the CBA and other ants' species data population were collected by the Malaysian Cocoa Board (MCB) researchers from February 2007 and ended in July 2009 as primary data. However, the other ant species data represented by either notation of present or absent, in contrast to CBA data with many ants counted for each cocoa tree. Subsequently, each cocoa tree's position was collected using a handheld Global Positioning System (GPS) to record the x and y coordinates location. Data processed using GIS software of ArcGIS in the projection system of Malaysia Rectified Skew Orthomorphic (MRSO). Tree coordinates combined with the attribute of the number of ants were converted into a shapefile in ArcGIS software (Table 1). There are four Plots of the cocoa area known as Plot A (one artificial ant nest on two cocoa trees or symbolized as 1N:2T), Plot B (one artificial ant nest on a single cocoa tree or symbolized as 1N:1T), Plot C (two artificial ant nests on a single cocoa tree or symbolized as 2N:1T) and Plot D (none artificial nest or symbolized as 0N:1T) and each plot represented by 50 tree points and accumulated to 200 sample cocoa trees in total each for every block (Block 18A and 10B). Figure 1 shows a cocoa tree position of the Block 18A. The overall methodology is shown in Figure 2.

Table 1. Data collection of CBA and other ants

Data Parameter	Year		
	2007	2008	2009
Temporal	Bi-weekly	Bi-weekly	Bi-weekly
Month	Jan - Dec	Jan - Dec	Jan - Dec
Number of ant calculated	Number (xls. format)	Number (xls. Format)	Number (xls. Format)
Number of cocoa tree sample	50	50	50
Plot	A,B,C,D	A,B,C,D	A,B,C,D

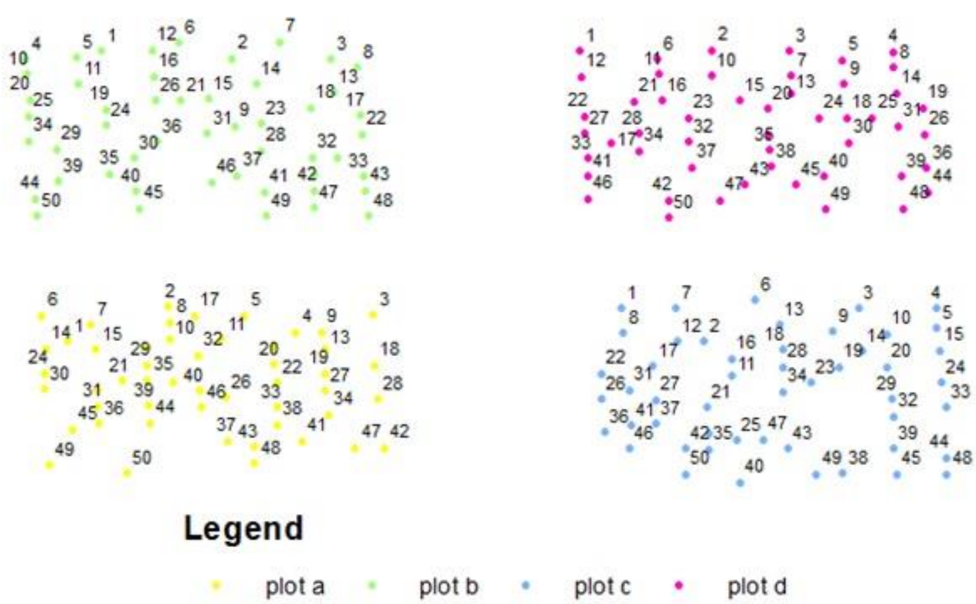

Figure 1. Cocoa tree position of the Block 18A

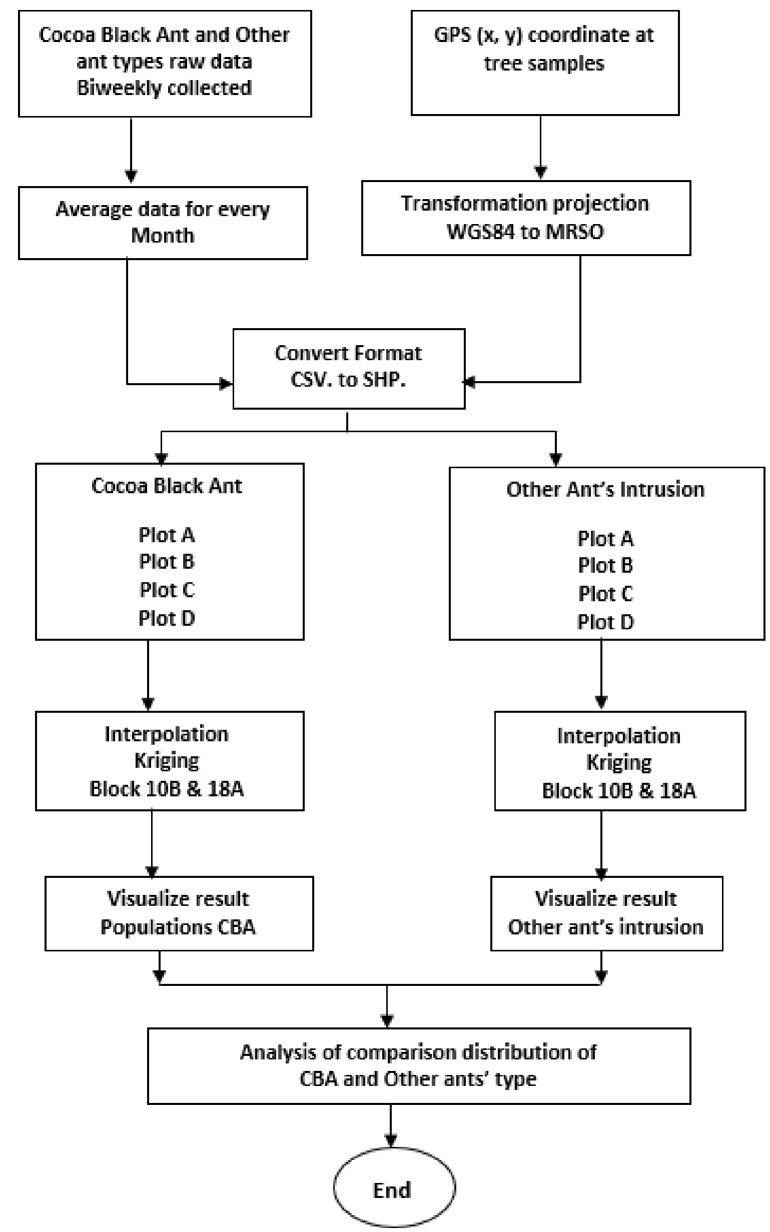

Figure 2. The overall methodology used in the experiment

Table 2. Classification of weightage for other ants' data collection

Data observation (First and second week data)	Weighting Categories	Description
0 + 0 = 0	0	No intrusion
1 + 0 = 1	1	Intermediate intrusion
0 + 1 = 1	1	Intermediate intrusion
1 + 1 = 2	2	Heavy/ Bad intrusion

The highest CBA population counted as the total number per tree could make a good relationship against other ant types (Saripah, 2014). The weightage for other ants is used to determine the level of intrusion and treat for the CBA. A value of zero (0) weighting category indicated the presence of CBA and classified as no intrusion or healthy condition if there is no disturbance from the other ants. Otherwise, a value of one (1) weighting category given to indicate the presence of the other ant species and classified as an intermediate intrusion (unhealthy condition), and a value of one (2) weighting category given to indicate the presence of the other ant species and classified as heavy/bad intrusion (unhealthy condition) as shown in Table 2.

In the ArcGIS data processing, the widely used interpolation techniques known as Kriging spatial data were incorporated to produce a population distribution map for the entire block. Kriging produces an estimate of the core surface by a weighted normal of the information, with weights declining with separation between the point distance of the information points (Junita, 2012; Adnan *et al.*, 2018; Brigss, 2010). The Kriging spatial interpolation was used due to it's the best method proposed by geospatialist in estimating the core surface by a weighted normal of the information. The method weights declining with separation between the point when the surface is being evaluated and the areas of the information points (Brigss, 2010) as the following equation:

$$\hat{Z}(S_0) = \sum_{i=l}^{N} w_i \, Z(S_i) \text{................}(1)$$

Where, Z (s_i) is the measured value at the *i*th location, w_i is an unknown weight for the measured value at the *i*th location, s_0 is the prediction location and N is the number of measured values.

Therefore, kriging interpolation will apply to the CBA population and other ant type species to visualize both ants' distribution. For each cocoa tree, the CBA population was classified as the highest population when every tree has more than 500 and reaches 1000 ants and however, when less than 500 cocoa black ants, it is the low population (Saleh *et al.*, 2020; Adnan *et al.*, 2018). Furthermore, methods that classify high, moderate, or low categories of CBA and other ants' distribution for each block were divided into four quadrants. If any quadrant has a CBA above 500 is considered high, and less than 500 is considered low. When the ratio is ¾ or all quadrants covered by the CBA above 500 is considered as high. While moderate when the ratio of half or ½ and cocoa black ants are lower at a ratio of ¼ or quarter (Adnan *et al.*, 2018).

Results and Discussion

Individual other ants' distribution according to block for four plots (A, B, C, D)

Data was collected at Blocks 18A and 10B, with four different plots, as explained earlier in the Methods section. There are many other types of ant species apart from beneficial ant species as CBA in a cocoa-coconut plantation system. The presence of the other species of ants will affects the availability of the CBA. The information on the presence of other ant species is taken, but the actual count numbers are not considered. According to the three categories classified earlier (i.e., no intrusion, intermediate, and heavy/bad intrusions), the individual other ants' intrusion is discussed further below. Plot A at Block 10B according to the years of 2007 until 2009 represented by the heavily/ bad intrusion on November and December (2007), May and September (2008), and March and April (2009). Plot B represented by the heavily/ bad intrusion in July 2007, September 2008, April and May 2009. Plot C is again represented by the heavily/ bad intrusion on February 2008 and May 2009. For Plot D heavily/bad intrusion as indicated by May, June, November, and December in 2007, June in 2008, and March in 2009. For the Plot A of Block 18A represented by the heavily/bad intrusion on May and June 2008. For Plot B, heavily bad intrusion as indicated by May and June 2008. Meanwhile, Plot C is represented by heavy/ bad intrusion on March until July and October (2008) and February (2009). For Plot D the heavily bad intrusion happened in March until July and September until December 2008 and January until June 2009.

Geovisualization comparison of other ants' distribution for two different blocks

To further understand the CBA's behavior and pattern, an analysis of the differences and similarities of other ant's intrusion for each block and Plots was performed. The comparison was made by investigating each plot for the same year, starting from 2007 to 2009 (i.e., 30 months). Only summary result (Table 3) for each Plot and years of the CBA and the other ants' intrusion was presented in this paper since extensive figures need to be included for every plot and year in these two different blocks. Several examples of other ants' intrusion maps were presented to elaborate on the findings. The findings discussed in this section assessed the qualitative relationship between CBA augmented nest and the other ant's intrusion conditions. Overall the result in Table 3 revealed that if the CBA dominated or highly populated inversely, the other ants' intrusion will be lower and vice-versa. A negative qualitatively interaction relationship between these two ant types existed in a cocoa plantation ecosystem.

Figure 3 shows comparison maps of the other ant's intrusion for Plot A in the year 2008. Block 10B shows that the heavy/bad intrusions classification occurs in September whereas, Blocks 18A has other ant's intrusion the heavy/bad intrusions classification in June. Figure 4 shows comparison maps of the other ant's intrusion for Plot B in the year 2008. Block 10B shows that the heavy/bad intrusions classification occurs in March and in September, whereas Block 18A has other ant's intrusion the heavy/bad intrusions classification in May.

Figure 5 shows comparison maps of the other ant's intrusion for Plot C in the year 2008. Block 10B shows that the heavy/bad intrusions classification occurs in June, whereas Block 18A has other ant's intrusion the heavy/bad intrusions classification in May until July. Finally, Figure 6 shows comparison maps of the other ant's intrusion for Plot D in 2008. Block 10B shows that the heavy/bad intrusions classification occurs in May. The Block 18A has other ant's intrusion in the heavy/bad intrusions classification in all months except for August. This indicated that no similar pattern of ants' intrusion happened from these two blocks, and generally, it has happened randomly. However, both blocks showed a similar pattern with an indicator if the CBA is higher than the other ants' intrusion will be lower. A study by Majer (1976) suggested that inter-specific ant in a cocoa plantation is due to several factors such as habitat requirements, inter-specific resource competition, and interspecific aggressive competition which in line with the findings in this research. Also, a study by Rubiana *et al.* (2015) stated that ant species richness and competition or interaction may occur due to the availability of resources such as food, shelter, potential nesting sites, as well as environmental conditions such as suitable temperature and light. The previous study indicated that other ant's intrusions often dominantly in each month with a lower CBA distribution that varies according to the cocoa cycle (Adnan *et al.*, 2017). This analysis revealed that the higher amount of artificial ant nests presented does not imply that the Plots' population condition will be better. The higher amount of artificial ant nests might have a complex, competitive level among the beneficial biological control of CBA (Saripah, 2014). The best number of artificial ant nests to be implemented is Plot B, with one 1:1 as opposed to Plot A (1:2) and Plot C (2:1), as discussed in this section. Therefore, to increase the number of CBA population in combating Cocoa Pod Borer (CPB) infestation that destroys the quality of cocoa beans inside a cocoa pod, one artificial nest for each cocoa tree suitable to be implemented by the cocoa growers in Malaysia.

Table 3. Summary results CBA and the other ant's intrusion

	PLOT A 1N:2T		PLOT B 1N:1T		PLOT C 2N:1T		PLOT D 0N:1T	
High CBA population	10B	18A	10B	18A	10B	18A	10B	18A
2007	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug
2008	Apr, Oct	-	May, Dec	Mar	Apr	Mar	Apr, Dec	-
2009	Jun	-	-	-	-	-	July	-
High Intrusion								
2007	Nov, Dec	-	July	-	Oct	-	Nov	-
2008	May, Sept	May, Jun	Sept	May, Jun	Jun	Apr, May, Jun, Jul	May	Except Aug
2009	Mar, Apr	Feb	May	-	May	Jan	Mar	All

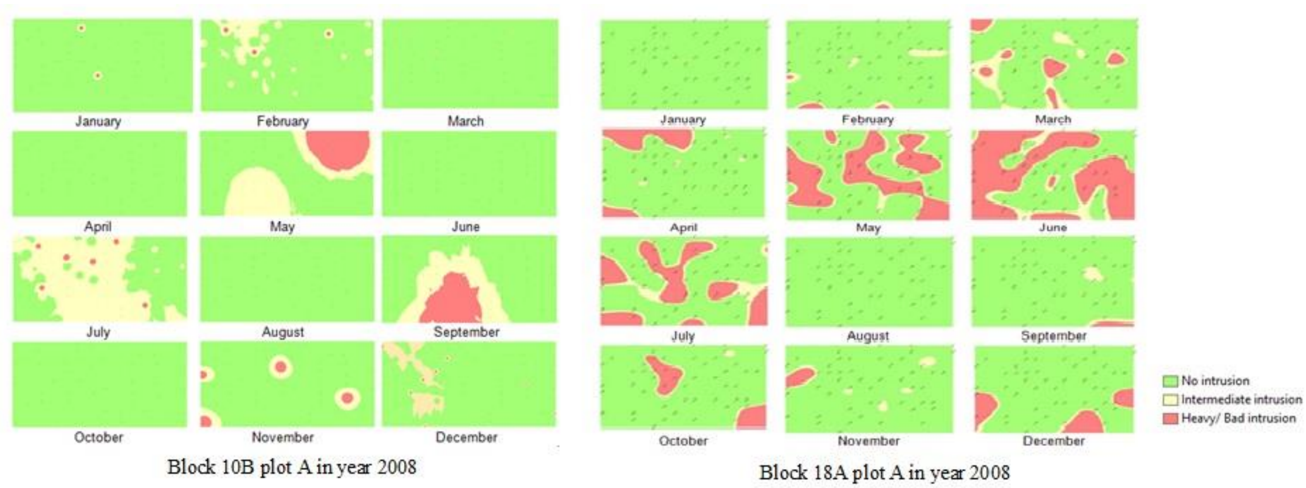

Figure 3. Comparison maps of the other ant's intrusion for Plot A in the year 2008

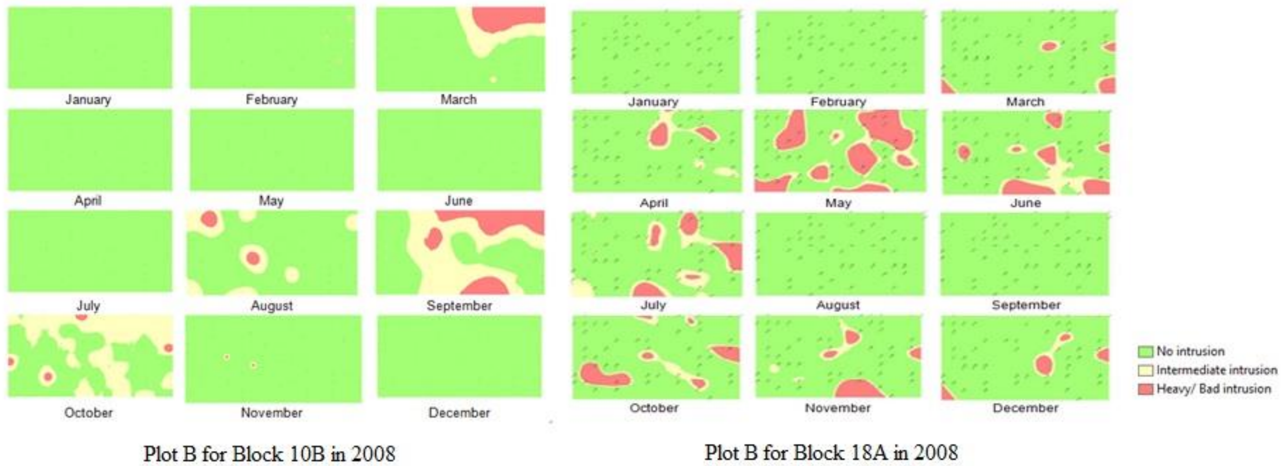

Figure 4. Comparison maps of the other ant's intrusion for Plot B in the year 2008

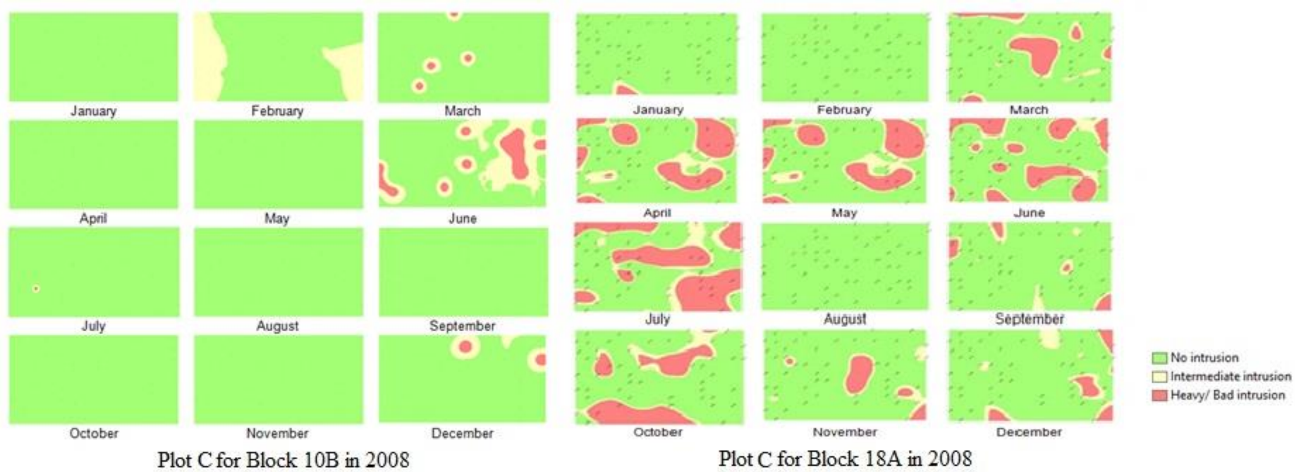

Figure 5. comparison maps of the other ant's intrusion for Plot C in the year 2008

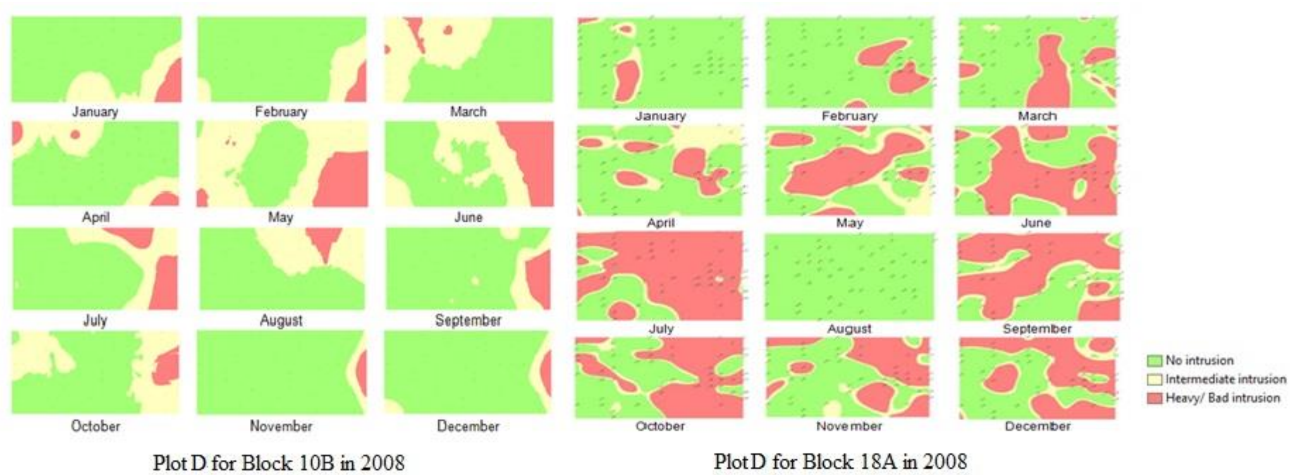

Figure 6. comparison maps of the other ant's intrusion for Plot D in 2008

Conclusion

The highest in CBA population could induce a strong, reasonable relationship against the other ant types. The artificial ant nest was introduced to increase the CBA population in controlling the infestation by the CPB for any cocoa trees. The GIS techniques used in this study revealed the negative geovisualization relationship between the existence of CBA with the other ants' intrusion (i.e., if the CBA is higher than the other ants' intrusion will be lower). Four study plots were investigated with different artificial ant nest ratios to the other ants' intrusion category. The study concluded that the plots with artificial ant nests (A, B, and C) showed the lowest intrusion rate, with a ratio of 1:1. Plot B indicated the best result, whereas plot without artificial ant nest (Plot D) the highest rate of an intrusion detected during the months and years of observation.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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