THE POTENTIAL EFFECTS OF CLIMATE CHANGE AND INSECT PEST DISTRIBUTION IN THE HIGHLAND REGION

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ABSTRACT

The agricultural industries in Malaysia have been negatively affected by climate change and global warming. Changes in the pattern of climate parameters, such as minimum and maximum temperatures, precipitation, and humidity, impact agricultural production. The phenomenon of temperature increase has a significant impact on insect dynamics, leading to the occurrence of insect outbreaks, particularly in regions characterized by high elevations. Based on the data provided by the Malaysian Meteorological Department (MET), there has been a documented rise in temperature in the Cameron Highlands region over the period from 1985 to 2020. The data presented in this study has been substantiated by the utilization of a data logger to record temperature data in the field. The interpolation analysis method implemented in ArcGIS 10.5 is employed to ascertain the spatial distribution patterns of climate parameters and insect pests inside cabbage farms. The results of the study indicate that the predominant pest of cabbage, Plutella xylostella, exhibited increased population growth in regions characterized by elevated temperatures and greater precipitation. Indeed, there has been an observable escalation in the migration patterns of insects into elevated geographical regions. Based on initial analyses, insects have exhibited a growing capacity for acclimating to elevated temperatures, heightened humidity levels, increased precipitation, and alterations in the atmosphere's chemical composition of the atmosphere as a consequence of insecticide application. This study aims to analyze the spatial distribution of insect pests in the highlands region and examine the correlation between their prevalence and the fluctuations in temperature patterns in highland areas.

Keywords: *climate change, pest, beneficial, brassica, agriculture*

INTRODUCTION

Climate change refers to long-term temperature shifts and weather patterns (UN, 2023). According to NASA, Climate change describes a difference in a region's average conditions, such as temperature and rainfall, over a long period. Most global climate models predict that rainfall patterns will change and storms will increase in severity (Anand et al., 2014). These shifts may be natural, such as through variations in the solar cycle. Nevertheless, since the 1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil, and gas.

Climate Change can be illustrated as a phenomenon that includes changing environmental factors like temperature, humidity, and precipitation over a long period (Shrestha, 2019). Due to increased temperature, elevated carbon dioxide CO_2 and other harmful gases, and irregular rainfall, global food production is under threat. Burning fossil fuels generates greenhouse gas emissions like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures. As a result, the Earth is now about 1.1°C warmer than it was in the late 1800s. The last decade (2011-2020) was the warmest on record (UN, 2023).

Climate change and global warming are significant concerns for agriculture worldwide, and they are among the most debated issues, particularly in relation to food security. Climate change and related phenomena, such as rising global temperatures and atmospheric carbon dioxide concentrations, are the focus of modern scientific research and agronomy. Temperature rise directly impacts pest reproduction, survival, spread, population dynamics, and the interactions of pests, the environment, and natural enemies (Anand et al., 2014). This is supported by Mafie (2022), who says that insects are poikilothermic organisms, meaning that their body temperature is affected by the temperature of their surroundings. As a result, the temperature is most likely the most influential environmental factor influencing insect behavior, distribution, development, and reproduction.

According to (Porter et al., 1991), The influence of climate on insect parasites is evident in the year-to-year fluctuations in insect populations caused by interannual variations in weather events and climatic conditions. Since insects are cold-blooded, their body temperature fluctuates with the ambient temperature, making them particularly susceptible to climate and weather. Temperature, precipitation, humidity, wind speed, and other climatic variables can directly impact parasites by affecting their development, reproduction, migration, and adaptation rates.

In addition, a direct impact of climate change may cause insect species to migrate to higher latitudes and disturb the general geographical distribution of insect pests. In return, a shift in insect population dynamics, insect biotypes, and multitrophic interactions will negatively affect the whole chain of agriculture globally (Sharma, 2014). Since insects can regulate their body temperature similarly or close to the surrounding environment, temperature has been considered as the most influential environmental factor influencing insect behavior, distribution, development, survival, and reproduction (Singh & Vennila, 2017). For instance, an increase in temperature promotes the *Spodoptera frugiperda* to develop faster within their optimal range of development (Du Plessis et al., 2020). If climate change leads to favorable conditions for pest attacks, Malaysia's national food security agenda is at risk. Hence, mitigation through a practical and scientific approach would be required to deal with this uncertainty.

Changes in climatic variables can either increase or decrease the population of pests. Species that are able to withstand the extremes of climate and acclimate to the altered environment are able to maintain their population and, as a result, consume crop vegetation. Compared to insect species found in tropical and temperate regions, species found in temperate regions are significantly impacted by temperature fluctuations. In temperate regions, insect invaders have exhibited a clear altitudinal shift and invasion of higher altitudes. This has created new sustainability challenges for agriculture (Shrestha, 2019).

The impact of increased temperature on the dynamics of crop pests increases in the number of pest generations, a likely expansion of their geographic range, interactions between natural enemies and pests, and pest management inputs. Insects are cold-blooded organisms; their body temperatures are comparable to their surroundings. Therefore, temperature is the most influential environmental factor on insect behavior, distribution, development, and reproduction. Some crop parasites exhibit "stop-and-go" temperature responses. They grow more quickly during periods of favorable temperatures. Increased temperatures will hasten the maturation of these types of insects, possibly resulting in more generations (and crop injury) per year (Awmack . et al., 1997; (Rozimah et al., 2022).

Any rise in temperature will inevitably affect the distribution of insects. It is predicted that a one-degree Celsius increase in temperature would allow the pace to increase by 200 kilometers (in the northern hemisphere) or 40 meters (in altitude) (Shrestha, 2019). For insect pests that produce one generation per year, their development takes several years, or the photoperiod limits the number of ages; climate change has little effect on the majority of facts. Species that are capable of producing two or more generations per year may progressively adapt to the new climatic conditions by shifting their temperature thresholds, effective temperature totals, and critical photoperiod lengths without exhibiting appreciable developmental changes (Trumble & Butler, 2009).

The diamondback moth (DBM), *Plutella xylostella*, is a cosmopolitan herbivore that feeds exclusively on crucifers. Population density of the DBM has been studied in various agroecosystems and is well documented on several crucifer plants (Muckenfuss & Shepard, 1994). Among other pests, the DBM is considered a serious pest of cabbage. The diamondback moth (DBM), *Plutella xylostella*, is one of the most destructive cosmopolitan insect pests of brassicaceous crops. It was the first crop insect reported to be resistant to Dichlorodiphenyltrichloroethane (DDT) which is one of the insecticides used in agriculture, and now, in many crucifer-producing regions, it has shown significant resistance to almost every synthetic insecticide applied in the field (Sarfraz et al., 2005). *Plutella xylostella* is the primary pest that inflicts damage on cruciferous plants, a commonly cultivated crop in the region of Cameron Highlands. The infestation of this insect results in significant economic losses of up to 90% for agricultural producers (Yusri et al., 2023).

In highland agroecosystems, the larval parasitoid *Diadegma semiclausum* has proven to be the most effective natural enemy of *P. xylostella* (Sarfraz et al., 2005). According to Macharia et al. (2005), the introduction of *D. semiclausum* in regions where cruciferous vegetables are cultivated is anticipated greatly benefit farmers and consumers of crucifers. Apparently, due to effective DBM control, certain parasites have become important. In certain mild highland regions where parasites (especially *Diadegma semiclausum*) provide effective control, *P. xylostella* has become irrelevant (Lim et al., 1998).

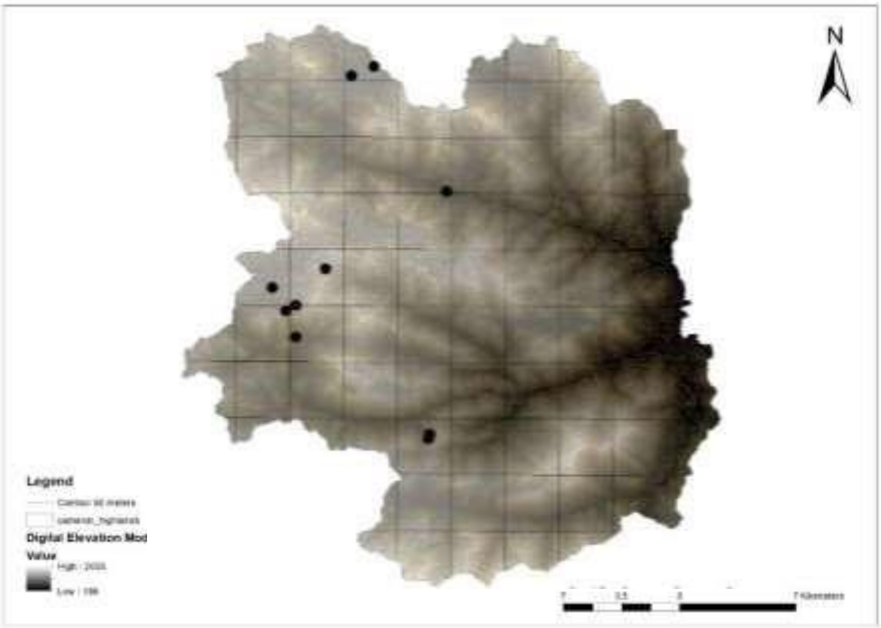
This research focuses on the highland region due to the significance of cabbage as a prominent cruciferous vegetable crop cultivated in the Cameron Highlands. The Cameron Highlands, characterized by its steep and extensively dissected topography, has emerged as a significant vegetable producer in Malaysia due to its ideal climatic conditions. Three popular vegetable types include cabbage, Chinese cabbage, and tomato (Aminuddin et al., 2005). According to Vegetables and Cash Crops Statistic 2021, Cameron Highlands is Malaysia's main producer of chili, eggplant, tomato and cabbage.

Hence, the primary aim of this research was to acquire comprehensive data and spatial distribution of pests prevalent in highland regions, which are concurrently impacted by climate change patterns.

RESEARCH METHODOLOGY

Study area

Figure 1: The study area



Cameron Highlands is located in the northwest region of Pahang, Peninsular Malaysia. It is situated at an elevation of 1829 meters above mean sea level and covers an area of approximately 712.8 square kilometers (Muaz Abu Mansor Maturidi et al., 2020). The highest peak in the Cameron Highlands is Mount Brinchang, 2031 meters above sea level. Cameron Highlands has three main sub-districts: Ringlet, Tanah Rata and Hulu Telom. Cameron Highlands is a moderate-temperature area and a crucial agricultural area in Malaysia. Cameron Highlands is a district on the Titiwangsa Range that encompasses 712,8 square kilometers. Mount Brinchang, which is 2031 meters above sea level, is the tallest peak in the Cameron Highlands.

The principal subdistricts of Cameron Highlands are Ringlet, Tanah Rata, and Hulu Telom. Cameron Highlands is a critical agricultural region with a temperate climate in Malaysia. The western region is drained by the Perak River system into the Straits of Malacca. In the east, the Cameron Highlands is discharged into the South China Sea by the Kelantan and Pahang River systems. The Cameron Highlands is located in the upper basin systems of these three main river systems and is generally more developed (Salleh & Ghaffar, 2010).

Topographically, refer to Figure 1, the study area contains roughly 50% mountainous areas, 30% undulating areas, 15% valleys, and 5% plains (Aik et al., 2021). The elevation ranged between 182 and 2065 m above mean sea level with an average annual precipitation of 2660 mm (Razali et al., 2018). This watershed has two distinctive peak periods of monthly rainfall amounts, with first peak rainfall observed in April and the second with higher rainfall volume in November (Teh, 2011). The area is surrounded by Kelantan and Perak from north and west, respectively and has the potential for growing a wide variety of vegetables, flowers, and other ornamental plants. The excellent climatic conditions in the highlands provide an opportunity for agricultural activities as the main business and attract many tourists (Gasim et al., 2012). The favorable climatic conditions in the highlands allow for agricultural activities as the primary industry and attract a large number of tourists.

Data collection and analysis.

This research was conducted in three different zones: the northern, central, and southern regions. Two Brassica fields and two Solanaceae fields are chosen from each zone for the insect identification procedure. Sampling methods use yellow sticky trap (YST), blue sticky trap (BST), insect nets and counting directly on plants. The collected insects will be transported to the laboratory for screening.

In addition, meteorological data were collected using a data logger in the study area. In this investigation, an OmegaTM Intrinsically safe temperature and humidity data logger and an OmegaTM Multiplexer Interface were used in this study. Historical data was obtained from the Malaysian Meteorological Department Power for 35 years, from 1985 until 2020. The climate data will be analyzed using the Geographical Information System ArcGIS 10.5.

Digital Elevation Model (DEM) satellite data is used in this study to produce a contour map using surface analysis in ArcGIS 10.5. In addition, ArcGIS 10.5 software was used to map insect distribution in the study area. Interpolation analysis is utilized to visualize the Cameron Highlands' weather change patterns. The Inverse Distance Weighted (IDW) technique is utilized to look at weather trends in 2021 and 2022. This study is ongoing and data collection is still being carried out in the field until 2025.

RESULTS AND DISCUSSION

Pest and Beneficial Insects Distribution in Cameron Highlands

Several factors influence the distribution of pest insects, including altitude, precipitation, temperature, and relative humidity. Geospatial mapping results show that insect distribution is concentrated in the central zone, followed by the northern and southern zones because of elevation (Figure 2). The elevation of the central and northern regions is between 1400 and 1500 meters above sea level, while the elevation of the southern region is approximately 1100 meters above sea level. *Plutella xylostella* is the predominant pest of brassica plants in Cameron Highlands. These pests occur in abundance most of the time. Despite the use of numerous insecticides by farmers, they are typically difficult to control. *P. xylostella* is no longer significant in some mild highland regions where parasites (particularly *Diadegma semiclausum*) provide adequate control. *Diadegma semiclausum* is a parasitic wasp species belonging to the Ichneumonidae family. The larvae of this beneficial insect feed on the larvae of the *P. xylostella* and other moths. Therefore, the distribution of beneficial insects, which are *P. xylostella's* natural enemies, is higher in the central and northern zones than in the southern zone (figure 3).

Figure 2: Distribution of pest population in Cameron Highlands

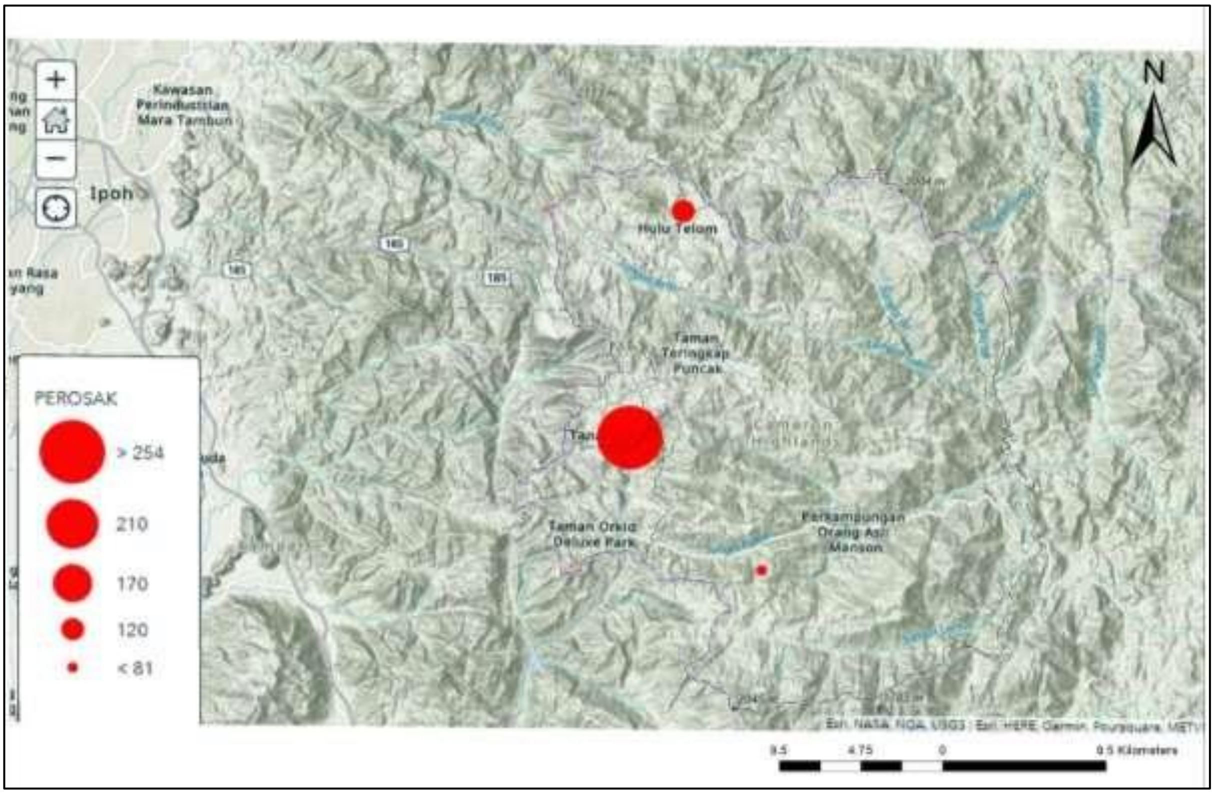
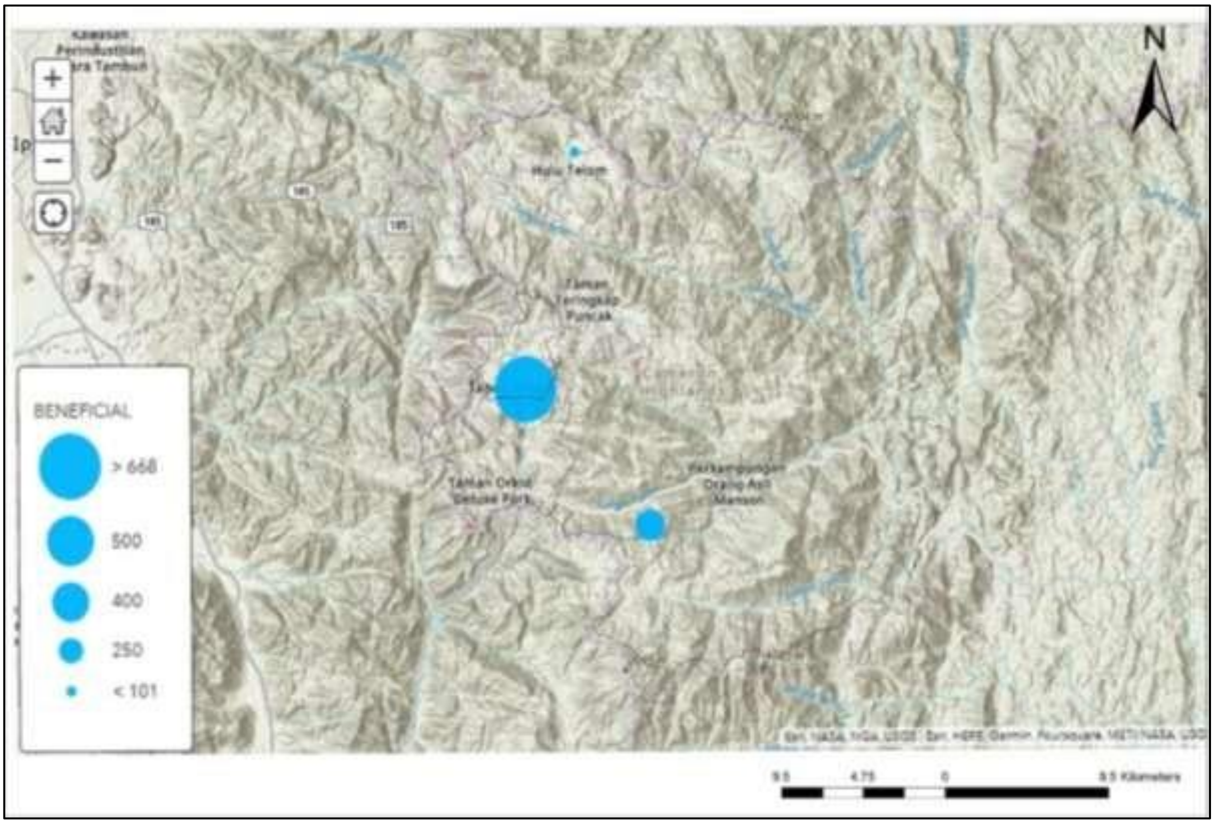


Figure 3:Distribution of beneficial population in Cameron Highlands



The historical climate in Cameron Highlands

Figure 4: Minimum, maximum, and average temperature

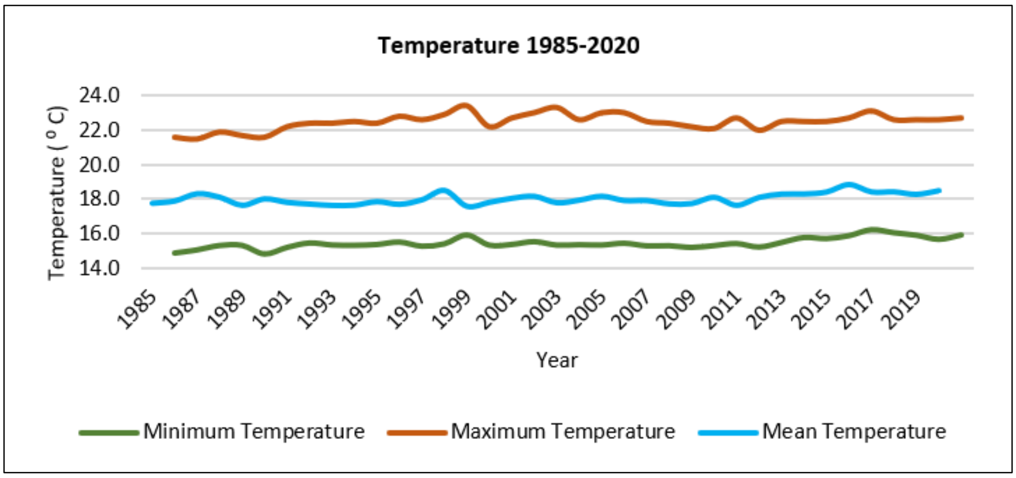


Figure 5: Rainfall distribution pattern

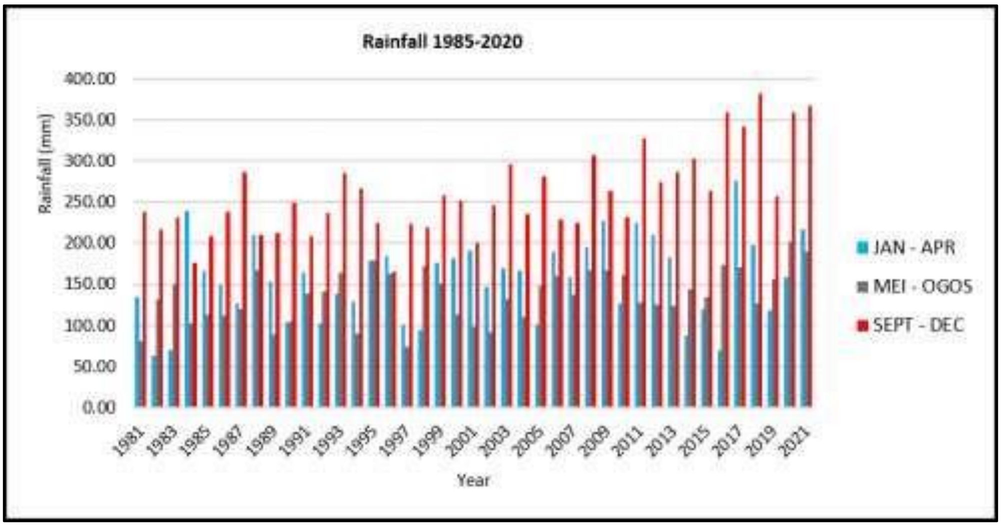
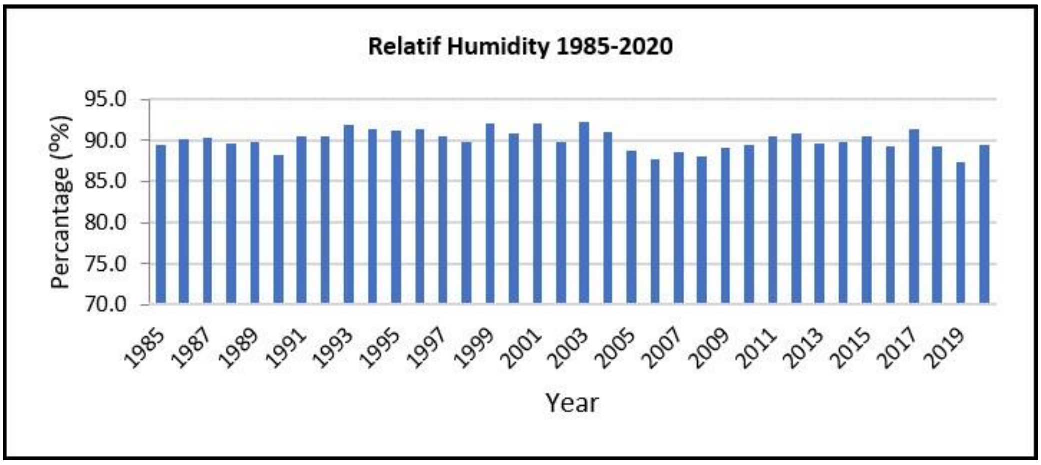


Figure 6: Relative humidity



Based on historical data in Figure 4, the minimum temperature range in the study area is 14.8 - 16.2 degrees Celsius and the average maximum temperature is between 21.5 - 23.4 degrees Celsius. The increase in minimum and maximum temperatures has caused the dynamism of highland ecosystems to change. Among the effects of temperature rise is that it favours the conditions for pests to migrate from lowlands to highlands. The physiology and metabolism of insects are regulated by temperature. An increase in temperature increases physiological activity and, therefore, metabolic rates. Insects must eat more to survive, and insect herbivores are expected to consume more and grow faster. This will lead to increases in the population growth rate of certain insects. Since they grow quickly, they will produce more offspring. Their population will grow, ultimately causing greater crop damage.

In addition, the increase in temperature affects the natural water cycle and increases the amount of rain in the study area. Based on the historical dataset in Figure 5, high rainfall occurs in Cameron Highlands during the northeast monsoon season, from November to March every year. The northeast monsoon will bring heavy rain in Peninsular Malaysia, Sabah and Sarawak. Increased rainfall in highland areas will cause the insect population to increase. On the other hand, increased precipitation can support fresh vegetation (food for insects) and facilitate insect population build-up. Figure 6 shows relative humidity readings between 80% and 90%, indicating that this region is very conducive to the insect life cycle.

Current climate condition in Cameron Highlands

Figure 7: Interpolation analysis of current temperature in Cameron Highlands during southwest monsoon

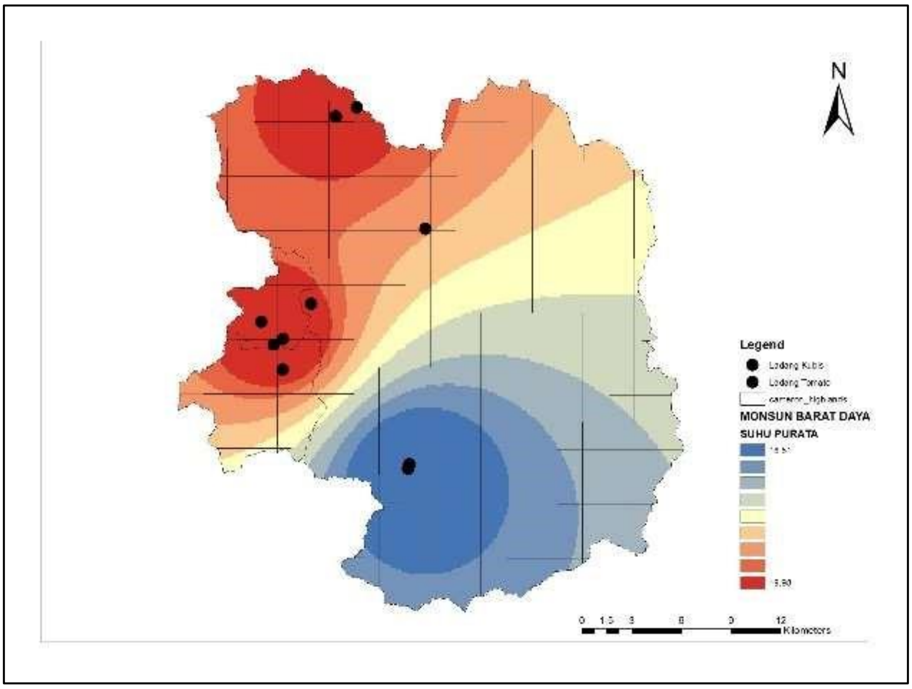


Figure 8: Interpolation analysis of current temperature in Cameron Highlands during monsoon transition

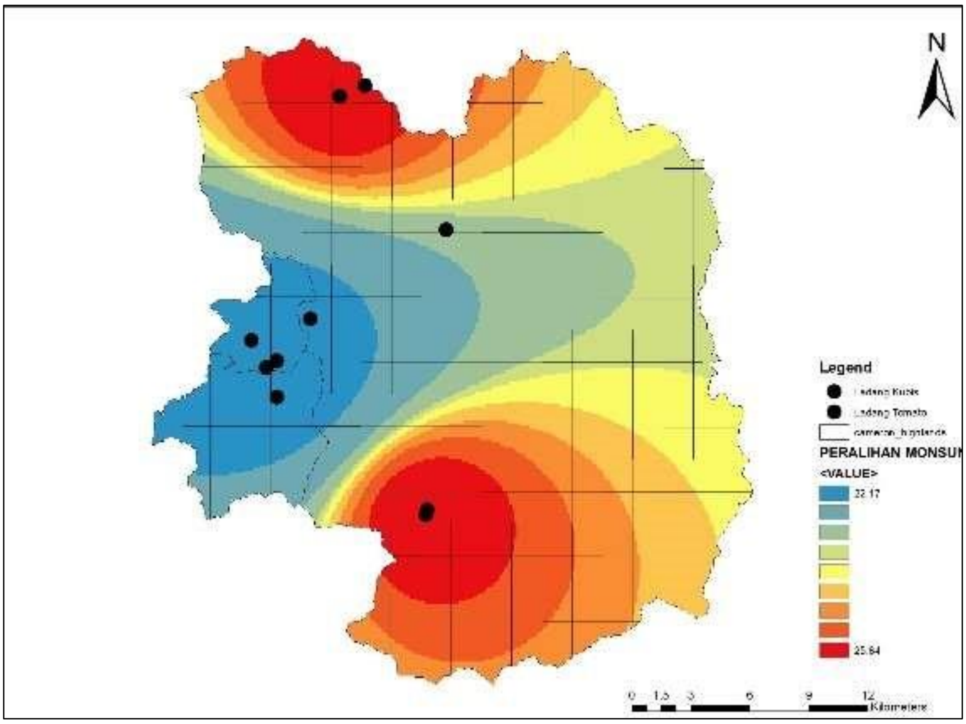
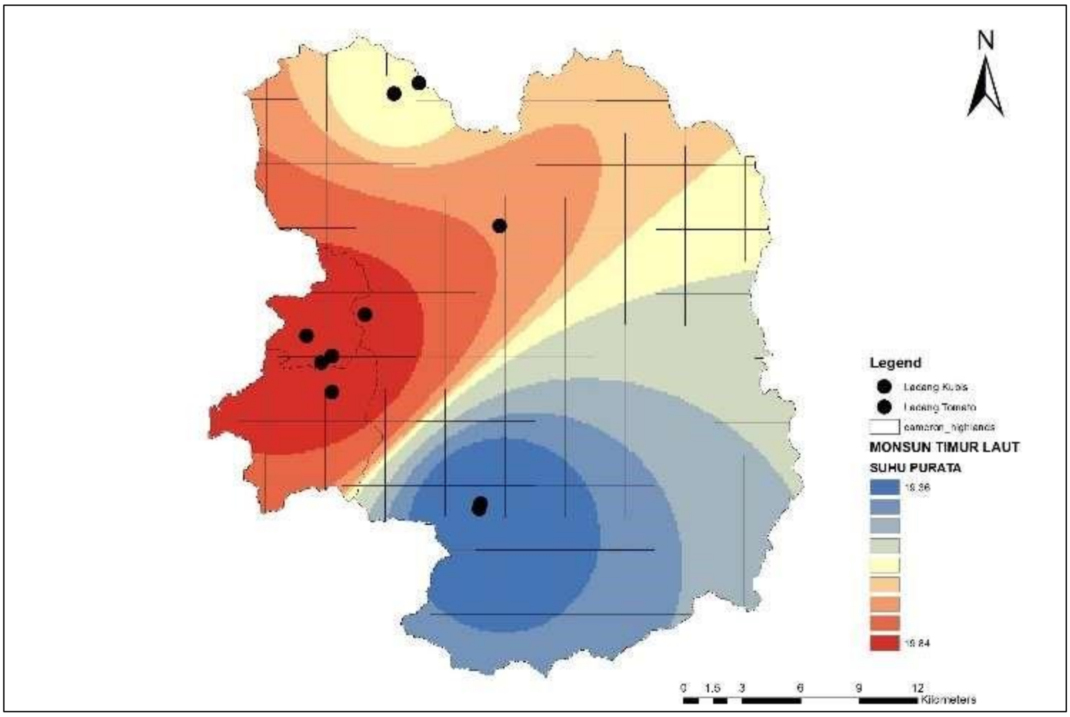


Figure 9: Interpolation analysis of current temperature in Cameron Highlands during northeast monsoon



The Inverse Distance Weighted (IDW) technique is utilized to look at weather trends in 2021 and 2022. It has shown that an increase in temperature has occurred in the study area during the monsoon transition season, with an average of 22.17 to 25.64 degrees Celsius (refer to Figure 7). During the monsoon transition, winds are weak from various directions, and it often rains heavily, but in October 2021, extreme heat hit Malaysia. This is due to Tropical Storm Kompasu, causing a consistent wind direction from the southwest in this region and bringing air humidity towards the tropical storm. Based on the IDW map that has been produced, the temperature is relatively low in the central zone compared to the north and south during the monsoon transition.

During the northeast monsoon season, heavy rain occurs in almost all areas (refer to Figure 8), making the temperature low between 19.36 and 19.85 degrees Celsius. During this season, the southern zone receives more rainfall than the northern and central zones. The same situation occurs during the southwest monsoon from May to September (Figure 9). This causes pests and beneficial insects to be concentrated in the middle zone.

CONCLUSION

Based on research, *Plutella xylostella* is the predominant pest of brassica plants in Cameron Highlands. The distribution of these pests is high in the middle zone, which is Tanah Rata. Even so, the distribution of beneficial insects, which are *P. xylostella's* natural enemies, is higher in the central and northern zones. The number of beneficial insect populations increases plants' resistance against *Plutella xylostella* pests without using insecticide sprays. The increase in pests in the Cameron Highlands also occurs due to the increase in temperature, which causes insects to adapt to the hot weather. Climate change can potentially change the distribution of pests globally and their resistance to pesticides. Climate change will affect agricultural plants and the insects associated with them. These effects are complex, but it is specific pest pressures will increase. There is a need for more insect monitoring, forecasting, and modeling so that we can develop adaptation strategies. In addition, countries should continue to monitor, share information, and use historical data and modeling to predict and prepare for an uncertain future that is expected to have hungrier insect pests impacting crop productivity and food security.

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