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Assessment of Climate Hazards Using PRECIS Regional Climate Model (RCM): A Case Study in Cameron Highlands, Pahang, Malaysia

ABSTRACT

This study aimed to assess the differences in modelling disaster risks results when using historical precipitation and when using simulated precipitation associated with future Intergovernmental Panel on Climate Change (IPCC) climate scenarios. Subsequently, the relationship between climate change and climate hazards was analyzed in this study. The secondary data analyzed included historical precipitation (1983-2017), flood and landslide events records, and Providing Regional Climates for Impacts Studies (PRECIS) regional climate model (RCM): A1B, A2 and B2 scenarios. By comparing the historical precipitation data with the RCM scenarios, the results showed that the precipitation was correlated with A1B scenario (r= 0.695). The relationship between climate change and hazards was identified to be a positive correlation. The historical daily precipitation (1983-2017) showed a positive correlation with flood and landslide events (r= 0.530, r = 0.797, respectively). As for prediction of climate hazards, the RCM A1B, A2 and B2 scenarios showed correlations with flood event: r= 0.648, 0.384 and 0.417, respectively. Similar results were obtained for landslide and the RCM A1B, A2 and B2 scenario: r = 0.498, 0.751 and 0.654, respectively. Precipitation simulation by PRECIS RCM indicated increased levels of precipitation in the Cameron Highlands for the 2018 - 2069. Commensurate with this, great possibility of increasingly serious consequential hazards such as flood and landslide events are expected.

Keywords: *climate hazards, PRECIS, regional climate model, Cameron Highlands*

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INTRODUCTION

Climate change has been a well-debated topic in international conferences for the past few decades. According to the United Nations Framework Convention on Climate Change (UNFCCC), climate change is a change of climate that is contributed by anthropogenic activities that directly or indirectly alters the composition of the atmosphere (*United Nations 1992*). The earth's surface temperature is increasing by 0.9°C on an annual average (*Stave and Leslie 2018*). Countless number of researches has been conducted to identify the causes of this increase in temperature, which is known universally as global warming. This phenomenon has been observed for the past decades and it poses threats to human population, economic, agriculture, food security and environment, all and sundry. For example, the drought experienced in Cape Town, Africa for the past three years that has led to extreme water scarcity is one of the most recent extreme events attributed to climate change (*Samuel et al. 2014*).

Climate change has resulted in various effects on different aspects such as ecosystem, human population and agriculture. Extreme events that occur throughout the world are those that are related to hazards, such as landslides, flash floods and droughts, causing loss of lives, property damages and economic losses (*Brunetti et al. 2002*). Climate hazards pose a high risk to human lives and the extent of damage could cost a huge loss to the economy. Different regional studies on climate change and climate disasters were conducted in different regions, such as the works of *Allen et al.* (*2010*), *Alexander et al.* (*2006*), *Dankers and Feyen* (*2008*), *Rianna et al.* (*2014*), *Huang et al.* (*2016*), *Gariano and Guzzetti* (*2016*), *Versini et al.* (*2016*), *Peruccacci et al.* (*2017*), *Naumann et al.* (*2018*), *Erler et al.* (*2019*) and *Teshome and Zhang* (*2019*). *Immerzeel et al.* (*2010*), *Singh et al.* (2011) and *Miller et al.* (*2011*) have found that the increase in earth's surface temperature has caused the decline of glaciers and snow cover in Himalayas that eventually resulted in floods. The accelerated decline in glaciers causes moraine-dammed lake to form and therefore increasing a potential outburst of a flood hazard.

In the past decades, rapid development in Cameron

Highlands in Pahang, Malaysia has contributed to the change of climate in the highlands (*Barrow et al. 2009*). Forest naturally transfers heat via evapotranspiration to the atmosphere and typically help in reducing the surface temperature by one or two degrees Celsius (*Chan et al. 2004*). The intense development that has converted the forested land into agricultural plantation and urban areas especially, have resulted in the changing of temperature and precipitation trends (*Chan et al. 2004*). In recent years, the occurrences of landslide and flood events have increased in Cameron Highlands. These tragedies have been reported by *The News Straits Times* (*2017*), *The Malay Mail Online* (*2016*) and *The News Straits Times* (*2018*). Although the effect of climate change can vaguely be seen directly through these reports, the unusual intense rainfall observed in the Cameron Highlands' major townships gives an indication of the effects of a warming climate.

Landslide occurrence has several triggering factors such as precipitation, reduced surface cover, slope failure, geological settings of site, weathering, subsurface water movements, and hydrological factors. Primary cause of landslides is water and slope saturation, and this depends on the precipitation, level of the ground-water, surface water, etc. Flooding also could cause landslides by slope saturation with water or undercutting banks of streams (*Amra and Fuad 2019*). Usually, landslide in Malaysia is due to natural degradation processes, which is triggered by heavy rain either by single heavy rain or by successive days of moderate rain (*Pradhan and Lee 2009*). Intense rainwater can cause failure of rock surface along fracture, joint and cleavage planes (*Sin and Chan 2004; Lloyd et al. 2011*). In addition, the moisture content of soil in turn increased the interstitial pore water pressure and seepage pressure. The moisture content adds weight to the soil and reduce cohesion force (*Pradhan and Lee 2009*). Thus, the presence of heavy boulders in the soil mass triggers the slide mechanism.

Gariano and Guzzetti (*2016*) argue that global warming is expected to increase the frequency and intensity of rainfall and hence landslide events. They also predict an increase in number of people exposed to landslide risk, and hence economy loss. *Peruccacci et al.* (*2017*) state that increment of mean annual precipitation may increase the thresholds of landslide. *Jakob and Lambert* (*2009*) study showed that landslides are resulted by hydroclimatic events. *Alexander et al.* (*2006*) synthesize climate change indices using daily temperature and precipitation data. The results showed that 70% of global land area had significantly decreased in annual occurrence of cold nights and significant increase in annual occurrence of warm nights. Moreover, results indicate significant warming throughout 20th century and precipitation indices show tendency of wetter conditions throughout 20th century. Previous study on global scale shows there is a relationship between climate change and occurrence of climate hazards.

Climate hazard is defined as physical events that causes harm to human health, livelihoods and natural resources. Climate risk is generated from climate hazard and vulnerability factors. Climate vulnerability has range of variables, which can be adopted according to study area and element of interest. Vulnerability factors are such as exposures (human health, damage factors, population density and property damage). The multiplication of climate hazard and vulnerability will generate climate risk which has range of risk. The generation of climate hazard and risk would assist in risk reduction and disaster management.

This study investigated the relationship between climate-related disasters in Cameron Highlands, with a local climate model and including the El Niño and La Niña phenomena. The results of this study will be useful for our public outreach programs, which educate the local people and authorities on effects of climate change in Cameron Highlands.

THE STUDY AREA

The Cameron Highlands is an area bounded with longitude 101°13'50" and 101°30'20" and latitude from 4°20' to 4°36'30" (*Matori et al. 2011*) (**Figure 1**). According to the *Department of Survey and Mapping Malaysia* (2002), it covers an area of 55 km^2 and the mountain area has been expanded to 712 km^2. It has an altitude range from 1,100 to 2,000 masl (*MDCH 2015*). According to the *MMD* (*2016*), the annual mean, minimum and maximum temperatures in the study area are recorded as 18, 9 and 25 °C, respectively. The average annual rainfall is recorded as 2,660 mm (*Matori et al. 2011*). Cameron Highlands is currently occupied by approximately 39,000 population. According to *Barrow et al.* (*2009*), the land use pattern has been changed from a permanent reserve forest status to agriculture land status due to continuous development. The agricultural land is divided into vegetables and flowers, tea plantations and indigenous cultivation. The development rate in the study area has been increasing rapidly with land clearing for new housing, hotels, apartment and agricultural activities that has resulted in land erosion and landslides (*Pradhan and Lee 2009*). Approximately 14 landslides have occurred within the project area

Figure 1. Location of Cameron Highlands with its major towns, water bodies and main roads.

in the last 20 years (*Public Works Department 2009*). In addition, the study area sits on steeply sloping area with 66 % of the slopes having a gradient of more than 20°. This would thus increase the susceptibility of the land towards erosion and landslides. Hence, it is crucial to study the climate change particularly based on the precipitation amount and climate hazard relationship in Cameron Highlands.

MATERIAL AND METHODS

Data collection

Secondary data were used to analyze the relationship between climate change and climate hazards for the study area. Based on the data, no drought events had occurred during the period of the study. Data and information were collected from relevant departments and institutions (**Table 1**).

The historical precipitation data (1983-2017) obtained from the Malaysian Meteorological Department (MMD) were the most essential for this study. Natural phenomena data of El Niño and La Niña were obtained from the National Aeronautics and Space Administration (NASA) portal. The data were extracted from the Niño 3.4 region. Niño region 3.4 is commonly used by scientists as the region that encompasses the western half of the equatorial cold tongue region, which provides a good measure of important changes in sea surface temperature (SST) and SST gradients that result in changes in the pattern of deep tropical convection and atmospheric circulation. The data on SST were collected with in situ measurements from ships and buoys, which produced the Hadley Centre SST (HadSST2) data set (*Bunge and Clarke 2009*). The HadSST2 measurements were then converted to anomalies by subtracting climatological values. The results were the Niño 3.4 region El Niño and La Niña and Oceanic Niño Index (ONI) (*Bunge and*

Table 1. Secondary data from the various relevant departments and institutions.

Departments/Institutions	Specification of data and information
Malaysian Meteorological Department (MMD)	Climate data such as number of rainfall days, rainfall amount (in millimeters), temperature and humidity from 1983 to 2017
National Atmospheric and Space Agency (NASA) portal	El Niño and La Niña phenomena occurrences and intensities from 1983 to 2017
Cameron Highlands District Office	Interview with experts on the occurrences and causes of landslides and flood events Landslides and flood events records
Malaysian Public Works Department of Cameron Highlands	Data related to landslide events in Cameron Highlands from 2010 to 2014
Newspapers (monograph)	Climate hazards occurrences report for Cameron Highlands
National Slope Master Plan	Landslide events record for Cameron Highlands.
Department of Irrigation and Drainage of Cameron Highlands	Flash flood events record for Cameron Highlands.
START Regional Centre, Chulalongkorn University	Providing REgional Climates for Impacts Studies (PRECIS) Regional Climate Model (RCM) for A1B, B2 and A2 scenarios (1983-2080)

Clarke 2009). These indices were used to determine any influence on the precipitation level and hazards events.

The climate disasters information, such as flood and landslides events in Cameron Highlands were gathered from different sources of the District Office of Cameron Highlands. In addition, certain technical documentations, such as the National Slope Master Plan, also provided the data of landslide events in Cameron Highlands. The dynamic downscaled Providing Regional Climates for Impacts Studies (PRECIS) regional climate model (RCM) was provided by the START Regional Centre, located at the Chulalongkorn University, Thailand.

The threshold value for potential flooding and landslide events in the future was determined by using average method. The PRECIS RCM was based on A1B scenario for average monthly precipitation (2018-2069). The threshold for flood risk was determined by calculating the average precipitation intensity for each flood event for 2011- 2017. The precipitation threshold was determined at 382 mm, hence, any future rainfall (2018-2069) higher than this value indicates a potential flood event.

The threshold for landslide risk was determined by calculating the average precipitation intensity for each landslide for the 1983- 2017. The precipitation threshold for landslide event risk was determined at 307 mm; hence, precipitation intensity above this value would potentially initiate a landslide.

Site visit

A total of three sessions of field investigations were carried out in the major townships of the study area. Discussion sessions were organized with local communities and Cameron Highlands district officer in order to understand the local climate scenario and occurrence of climate disasters in the study area. Information on flood and landslide events retrieved from the archives at the District Office of Cameron Highlands were categorized based on location, fatalities and estimated cost of loss.

Data analysis

The software used for statistical analysis was the Statistical Package for the Social Science (SPSS) version 22. The software was able to process data using various statistical options, such as descriptive statistics, measure of central tendency and linear regression (*Calvin 2011*).

The SPSS also provides an easy alternative to create scatter plots, which able to illustrate the relationship prior to the statistical test.

Annual average and monthly average historical precipitation were analyzed. The simulated data utilizing PRECIS RCM precipitation of A2, A1B and B2 scenarios were analyzed for the same period. The *IPCC* (*2000*) suggested three scenarios that describe climate change projections. These scenarios are:

A1 Scenario. The A1 scenario family assumes very high economic growth, global population peaking mid-century and then declining, and energy needs being met by a balance of fossil fuels and alternative technologies. A1B (a subset of the A1 family) lies near the high end of the spectrum for future greenhouse gas emissions, particularly through mid-century. A1B projects a future where technology is shared between developed and developing nations in order to reduce regional economic disparities.

A2 Scenario. The A2 story line is characterized by heterogeneity, self-reliance and local identities are emphasized, and population increases continuously.

B1 Scenario. The B1 scenario family lies near the lower limit of projected changes in greenhouse gas emissions. The B1 scenario assumes global population growth peaks by mid-century and then declines, a rapid economic shift towards service and information economies, and the introduction of clean and resource-efficient technologies.

Descriptive analyses on mean, standard deviation, maximum and minimum precipitations were determined using the SPSS software. Descriptive charts were plotted for the monthly mean precipitation for the historical and regional climate model to show the variation. The mean and standard deviation of each variable represents the average conditions over the 30 years data period.

The Pearson correlation and linear regression were applied to establish a relationship between precipitation data and climate hazards. Pearson correlation analysis was used to compare the historical precipitation with the PRECIS RCM projections. It is aimed to observe the correlation and determine which climate scenario is closely related to the historical precipitation. Based on *Campbell* (*2013*), the Pearson regression coefficient, r value is classified as $0.2 \leq |r|$ as weak relationship, $0.4 \leq |r|$ as moderate relationship, $0.6 \leq |r|$ as strong relationship and $|r| > 0.8$ as very strong relationship.

Linear regression was used to analyse the degree of relationship. For linear regression validation, six assumptions have to be fulfilled. The first assumption- there should be linear relationship on a scatter plot. The second assumption- the precipitation variable and climate hazards should be continuous (i.e., there are interval or ratio). The third assumption- there is no significant outlier. The fourth assumption- the data should show some homoscedasticity, where the similar variation between variables along the line of best fit can be observed. The fifth assumption- the residual plot of regression line should be approximately distributed in the model. The sixth and last assumption- there should be independence for the historical precipitation variable. As some outliers were found, where it had significantly affected the fit of the regression equation, five out of six assumptions were fulfilled. This indicated that the use of linear regression was valid.

RESULTS AND DISCUSSIONS

Comparison of Historical Precipitation with Projections from the PRECIS Regional Climate Model (RCM) A1B, A2 and B2 Scenario

The historical precipitation (1983-2017) and regional climate model A1B, A2 and B2 scenarios of Cameron Highlands were analyzed according to the average annual rainfall. The simulated average annual precipitation based on the A1B scenario was recorded as 2,599.47 ± 255.55 mm, which is similar to the historical data (2,616.18 ± 474.50 mm) (**Table 2**). Based on the Pearson correlation test, high correlation coefficient (r= 0.695) was obtained for the historical precipitation and the A1B scenario projections. This is an indication that the climate model in Cameron Highlands has similar trend as the A1B scenario storyline.

Based on the PRECIS RCM simulation, higher average annual precipitation was observed in the A2 and B2 scenario (2,990.67 ± 354.35 mm and 3,240.11± 509.13 mm, respectively). The historical precipitation and A1B scenario data recorded similar results as it explained the current emission situation under the fossil fuel intensive level as highlighted by *Matori et al.* (*2011*).

Occurrences of climate disasters, such as landslides and floods have significant linkage and bearing with the precipitation intensity. The average monthly precipitation and the PRECIS RCM A1B, A2 and B2 scenarios were applied (**Figure 2**). The monthly precipitations were analyzed for the 1983-2017. The average precipitation showed a diurnal pattern with the first peak in the period of March-April-May and the second peak in the period of September-October. Likewise, the A1 scenario showed the highest average monthly precipitation in the same periods. A similar result was obtained by *Loh* (*2015*) on the monthly average precipitation. The A2 scenario had higher annual average of precipitation level as the scenario had no concern on the emission limit and therefore, may enhance climate change in the future, thereby influencing the precipitation pattern. The study of *Dankers and Feyen* (2008) showed a similar trend for the A2 scenario in Europe, which was linked to increased risk of river flooding.

Relationship between Climate Change and Hazards

Extensive studies on climate change particularly for precipitation levels, showed effects on the occurrences of climate hazards, such as flash floods and landslides. Hence, establishing a relationship could provide an idea on the strength of the relationship. Flood events used data from 2011-2017. However, the historical precipitation data were obtained from the Malaysian Meteorological Department for the period of 1983- 2017. Hence, the data input was standardized based on 2011- 2017 period. The relationship between flood events and historical

Table 2. Descriptive statistics of average annual precipitation for historical observations and scenarios simulations in Cameron Highlands weather monitoring station (data from 1983 to 2014).

Average Annual Precipitation	Mean (mm)	Standard Deviation (mm)
Historical data	2,616.18	474.50
A1B	2,599.47	255.55
A2	2,990.67	354.35
B2	3,240.11	509.13

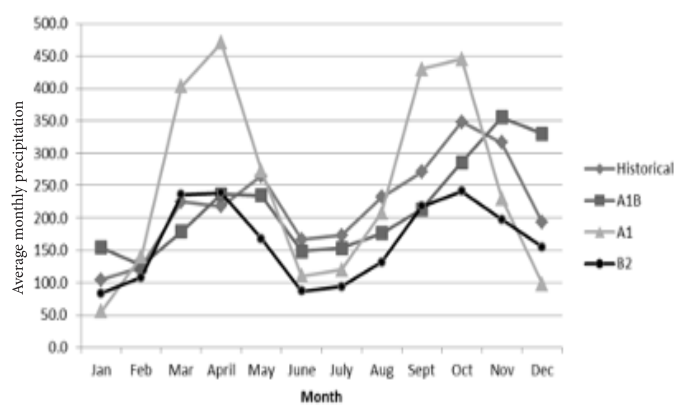

Figure 2. Average monthly precipitation (mm) for historical observations and PRECIS regional climate model (RCM) based A1B, A2 and B2 simulations in Cameron Highlands weather monitoring station.

precipitation showed a strong relationship (r=0.530) with 28% total variation between precipitation intensity and flood events. However, the regression established a poor fit for the data as the significance value is p=0.076 (**Table 3**).

The A1B scenario and flood events showed a strong relationship (r= 0.648) with 42% of variation in precipitation intensity and flood events data. In addition, the regression established a good fit as the significance is p=0.023. There is a weak (r= 0.384) and moderate (r= 0.417) relationship between A2, B2 and flood events, respectively. The correlation for A2 and B2 scenario showed poor fit line for the data hence, no statistical significance with p=0.218 and p=0.178, respectively. Positive correlation indicated that the increase in precipitation intensity also increases the probability of flood occurrence. Besides, the results also indicated that the historical precipitation intensity was closely related to the A1B scenario as it showed similar correlation strength.

Table 3. Linear regression output for flood events with historical precipitation and PRECIS A1B, A2 and B2 scenario simulations flood event occurred in Cameron Highlands (2011-2017).

Item	Pearson correlation	R square	Significance[a]
Flood events and monthly precipitation	0.530	0.281	0.076
Flood and A1B scenario	0.648	0.420	0.023*
Flood and A2 scenario	0.384	0.147	0.218
Flood and B2 scenario	0.417	0.174	0.178

[a] Linear Regression
* Significant level α <0.05

Table 4. Linear regression analysis for landslide events, historical and scenarios precipitation data Landslide events occurred in Cameron Highlands (2011-2017).

Item	Pearson correlation	R square	Significance[a]
Landslide events and monthly precipitation	0.797	0.636	0.002*
Landslide and A1B scenario	0.498	0.248	0.099
Landslide and A2. scenario	0.751	0.564	0.005*
Landslide and B2 scenario	0.654	0.428	0.021*

[a] Linear Regression
* Significant level α <0.05

In order to determine the relationship between landslide and precipitation intensity, data for landslide event (1961-2017) were obtained from the Cameron Highlands District Office (**Table 4**). The analysis was conducted for the period of 1983-2017.

The historical precipitation and landslide events showed a high degree of correlation coefficient (r= 0.797) with 63.6% of variation in data. In addition, the regression had a good fit line hence, a statistically significant value (p= 0.002). The linear regressions between landslide events and PRECIS RCM scenarios had shown a strong correlation with A2 (r= 0.751) and B2 (r= 0.654) and weak correlation with A1B (r= 0.498). The A2 and B2 had good line of fit with p=0.005 and p=0.021, respectively. There was no statistical significance (p= 0.099) for the A1B scenario.

Positive correlation indicated the increase in precipitation level thus increases the probability of landslide events. There was a strong correlation between historical data and the A2 scenario. Hence, the landslide had similar trend as the A2 scenario, which lacked control for regional development and less efficient technology that are major concerns according to the IPCC definition. Besides, the B2 scenario showed a weak correlation for landslide and flood occurrence. The B2 scenario focuses on sustainable development, whereby the emission is under control and below the threshold level, which returns the climate system to a balance. However, there was a possibility that the relationship was not conclusive as the RCM data for the B2 scenario as the model was simulated for the 2010- 2069 only.

Trenberth (*2011*) reported that the increase in greenhouse gases (GHGs) has direct effect on the precipitation levels. GHGs contribute to the increase in earth's surface temperatures where evaporation increases, resulting in surface drying hence, cause the prolonged drought event. An increase of 1°C of global temperature increases the water holding capacity of air by 7%. Therefore, this increases the water vapor in the atmosphere. Hence, the potential occurrence of intense rain is supplied with the increase of water vapor in the atmosphere. This increases the risk of flooding due to rainfall intensities above the threshold levels. In addition, *Pielke and Downton* (*2000*) stated that the increase of precipitation could increase property damages caused by flood. The occurrence of flood events in Cameron Highlands was mainly contributed by the precipitation intensity. Positive correlation by PRECIS RCM indicated the precipitation intensity may directly affect the probability of hazards events. However, the precipitation level can be influenced by evaporation, temperature, wind speed, wind direction and natural phenomena, such as El Niño and La Niña.

In certain parts of the world, increases in extreme events during La Niña phenomenon were reported. *Cai et al.* (*2015*) reported that cold anomalies of La Niña in 1998 extended farther west with greater extent of impacts. Floods, landslides, shortages of food and water -borne diseases affected approximately 250M people in China and Bangladesh during La Niña event in the period of 1998-1999. *Peras et al.* (*2008*) revealed that strong typhoons, droughts (associated with El Niño) may cause negative impacts in the agricultural sector compared to other climate-related stressors. As this is of concern, this study also analyzed the linkage between El Niño, La Niña and flood events during 2010-2014.

The flood events that occurred from 2011 to 2014 were due to increase of precipitation. The La Niña phenomenon (Strong negative SST Anomalies Index) started in May 2010 (**Figure 3**). It was initiated by the increase in precipitation level and followed by number of flood events in the study area. Similar patterns were observed for landslides. During the La Niña phenomenon, the sea surface temperature decreased below average condition thereby inhibiting formation of rain clouds over the eastern equatorial Pacific region. At the same time, it enhanced rainfall over the western equatorial Pacific region such as Malaysia, Indonesia and the northern part of Australia (*Lee 2015*).

In this study, the established relationship between precipitation and climate hazards showed a positive correlation whereby an increase in precipitation will increase flash flood occurrences. This is an indication that anthropogenic activities should be controlled by the implementation of policies and international treaties, such as Kyoto Protocol and Paris Agreement to reduce the GHGs emission by ratified countries, which in turn could decelerate global warming and its harmful effects. Hence, reduction in GHGs will return the precipitation to normal average level and the hazards frequency is assumed to be reduced significantly.

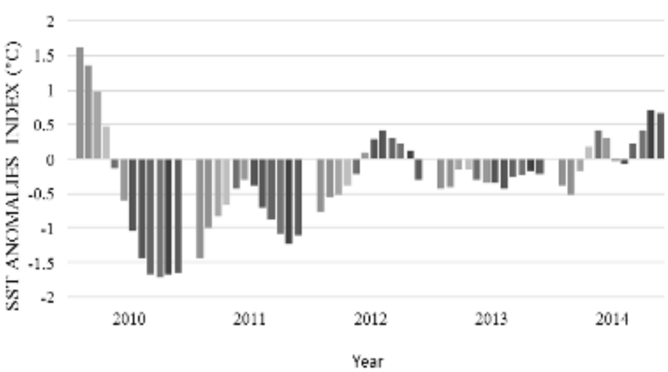

Figure 3. Equatorial Pacific Sea Surface Temperature (SST) Anomalies Index (2011 to 2014).

Prediction of Climate Hazard Risk Using the PRECIS Regional Climate Model (RCM)

The simulated precipitations for the 1983-2017 and the 2018-2069 were analyzed to predict climate hazards occurrence. In order to determine the flood hazard risk, the A1B scenario (**Figure 4**) was used to predict for flood and landslide events as it has the highest correlation with historical flood record (r= 0.648). The prediction was developed to determine the potential of hazards occurrences in the future. This prediction aims to reduce life loss, property damages and economical loss by providing early warning information to local authorities.

Prediction of flood risk using the PRECIS RCM A1B Scenario

The precipitation threshold was determined at 382 mm, hence, any future rainfall (2018-2069) higher than this value indicates a potential flood event. A total of 11 monthly precipitation intensities were identified, to be greater than the threshold level in this study. Potential flood risk threshold (>382 mm) was determined for the March - April , and November – December. The periods with the potential to exceed the threshold level are November 2021, March 2028, March 2040, December 2043, April 2045, March 2046, March 2054, April 2061, November 2063, December 2065 and April 2069.

March-April-May and October-November-December are recognized as the monsoon season

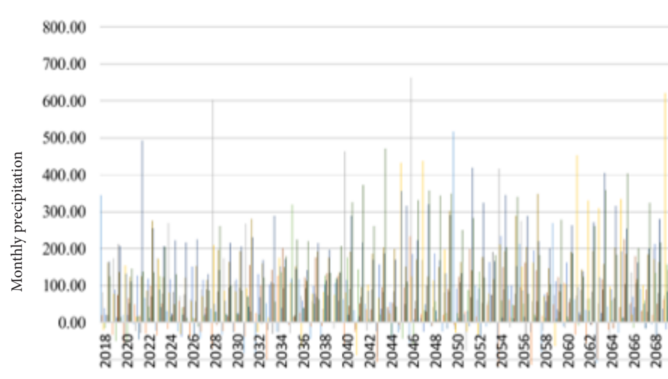

Figure 4. Average precipitation simulation Cameron Highlands based on the A1B scenario (2018-2069 period).

inter-exchange periods, and higher rainfall intensity is usually observed in Peninsular Malaysia. The simulated precipitation based on the A1B scenario indicates an increase in precipitation level in the future. Hence, the increase in precipitation will increase the possibility of flash flood events.

Prediction of landslide risk using the PRECIS RCM A1B Scenario

The threshold for landslide risk was determined by calculating the average precipitation intensity for each landslide event for 1983- 2017. The precipitation threshold for landslide risk was determined at 307 mm; hence, precipitation intensity above this value would potentially initiate a landslide. According to the *DID* (*2010*), soil is usually susceptible to rainwater erosion. This proves that landslide risk threshold is lower than threshold for flood risk.

The PRECIS RCM A1B scenario was used to predict the future precipitation levels and landslide events. The highest precipitation intensity was observed in the period, of March-April-May and August-September-October. A total of 168 monthly precipitation intensities greater than the threshold level were identified for 2018 - 2069 . The wettest month was April, therefore, higher landslide risk (>307 mm) was predicted, followed by the month of October.

The PRECIS RCM A1B scenario from 1983 to 2069 showed an increasing future precipitation level trend. The increase in precipitation in the future would likely increase the number of landslide events in Cameron Highlands. Without any intervention, the local climate model should follow the A1B scenario storyline where the growth of economy and population will increase the GHGs emission. This will further hasten the changing of the climate in Cameron Highlands. The increment of average temperature will directly increase the evaporation rate and the precipitation rate. Consequently, higher landslide events are predicted in Cameron Highlands.

By comparing with the A1B scenario, it has indicated that there would be an increase in future precipitation levels. Both scenarios have similar emissions and is dominated by economic and population growth. Hence, this will contribute to the increasing level of greenhouse gases (GHGs) and therefore contributing to more global warming. Global warming has a direct effect on the precipitation level (*Trenberth 2011*). As discussed earlier, the increase in global temperature would increase the precipitation level in certain regions and initiates the effect on natural phenomena, such as El Niño and La Niña. Therefore, conservation and alternative resources of energy should be used to minimize the GHGs emission and the economic prospects should be practiced in a sustainable way in order to reduce the effects of climate change. Similar results were reported by *Meehl et al.* (*2005*), *Sheffield and Wood* (2007). These studies indicated that in the tropical regions, the impacts will be the increase in sea surface temperature (SST) with increase in evaporation and precipitation onto most land surface. With prediction of precipitation, any indication of precipitation above the threshold level will be an early warning to the public. This will also serve as a useful guideline for a better disaster management strategy, which could help minimize the cost of damages, loss of lives and properties.

CONCLUSION AND RECOMMENDATIONS

The rainfall pattern in Cameron Highlands would be similar to the PRECIS RCM A1B scenario. The development in Cameron Highlands would likely go towards industrialization. However, deforestation and the lack of green technology application is envisaged to increase the emission of greenhouse gases (GHGs). This will contribute to global warming. The occurrences of floods and landslides showed a positive correlation with the precipitation intensity, where the hazard risk thresholds were determined in this study. However, the precipitation intensity was also influenced by the natural phenomena El Niño and La Niña, which respectively potentially decrease and increase precipitation levels.

The release of GHGs is just the beginning of a disaster cycle whereby the increase triggers more global warming and further climate change. It is then followed by changes in hydrological cycle, rainfall pattern, El Niño and La Niña phenomena. The occurrence of flood and landslide events in Cameron Highlands would depend on the factors mentioned above. This study suggests that with the future increase in precipitation levels, there would likely be more serious hazard events affecting Cameron Highlands. Therefore, the local land development policy and the National Climate Change policy should be invoked appropriately to take cognizance of the efforts needed to reduce the GHGs emission in the local environment immediately. The Malaysian Government has no choice but to encourage the public to practice sustainable economy in Cameron Highlands to have a balance between development and environmental conservation. This is utmost important to practice development, bearing in mind the climate change calamity of higher precipitation levels.

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