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VULNERABILITY OF AGRICULTURE TO CLIMATE CHANGE EVENTS IN THE UPPER BASIN SYSTEM: A REVIEW

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ABSTRACT

Highland regions in Malaysia are mainly linked with the watershed of the primary river system due to their geomorphological forms, habitat characteristics, and dynamic ecosystem. Malaysia's economic development has caused a high demand for natural resources for more than half a century. It has resulted in environmental issues, particularly in the highlands region. The rapid development caused the temperature in the highlands to increase tremendously, affecting the environment's physical processes and posing a threat to humans. Rising temperatures also threaten the economy of the upland population who depend on agricultural activities. Climate change also indirectly invites natural disasters by increasing rainfall above normal levels and causing slope failure and mudslides in the highlands. Temperature and precipitation changes will cause changes in land and water cycles, affecting agricultural growth and productivity. Temperature rise directly affects pest reproduction, survival, spread, and population dynamics which will cause damage to plants. This paper addresses the issue and challenge of climate vulnerability and the need for a comprehensive approach to more climate change scenarios.

***Keywords**: climate change, temperature, agriculture, vulnerability, upper basin*

INTRODUCTION

The upper basin system is an area rich in water resources and biodiversity. After independence, rapid development occurred in the western part of peninsular Malaysia, including the highlands. Rapid exploration takes place extensively, particularly in the Titiwangsa Range, which features a diverse ecosystem with high-quality timber and fertile farmland. The Titiwangsa Range is the primary upper basin that feeds the peninsula's major rivers. According to Salleh and Ghaffar (2010), numerous highland regions are comprised of the Upper Perak - Galas, Upper Pergau, Upper Kinta - Jelai, Upper Jelai - Tahan, Upper Selangor - Semantan, and Upper Endau - Rompin river systems. This statement is supported by (Rozimah & Khairulmaini, 2016), which states that the Cameron Highlands, a highland region drained by the upper basins of the Perak, Pahang, and Kelantan river systems, is among the most exploited of these upper river basins. This is because Cameron Highlands is a highland tourist destination known for its cold climate. The climate of Cameron Highlands is conducive to agricultural activities and numerous tourist attractions, including tea plantations, flower gardens, strawberry farms, and vegetable farms (Abdullah et al., 2019)

Uncontrolled development, notably in the agricultural sector, leads to illegal land clearing in several regions, which has detrimental consequences such as landslides after heavy rains. Recent unpredictability in the weather has resulted in more significant precipitation in Malaysia in recent years. Even when it was not monsoon season, the Cameron Highlands had heavy precipitation. This weather unpredictability is also a consequence of the scenario of climate change. In the past decade, the severity and frequency of environmental degradation processes, such as the effect of climate change on temperature rise and natural disasters, have progressively grown.

Throughout history, highland farmers have spontaneously adapted to climate change (Anwar et al., 2013). Nonetheless, deliberate and transformational modifications will be required, as significant and discrete climate change is expected by the end of this century. In light of these factors, this analysis focuses on river basin and farm-level responses to climate change's geographical and temporal difficulties. In this examination of the susceptibility of agriculture to climate change, the nature, scope, and effects of climate change are investigated and evaluated. Adapting agriculture to climate change requires consideration of these factors.

Climate change is a scenario that is threatening the world. Continuous temperature rise affects agricultural activities and will threaten food security. Highland agricultural areas, especially in Cameron Highlands, are particularly affected by the increase in temperature as temperate climate vegetables require a temperature of 18-21 °C for crops. Climate change also affects the hydrological cycle in water catchment areas and the water resources used to irrigate crops, especially for small farmers who are still depend on the weather. The agricultural sector will be more vulnerable and less resilient to climate change scenarios. Therefore, an integrated approach needs to be implemented for both the short and long term to be applied by farmers. The vulnerability and adaptation of the agricultural sector in the upper basin system to the challenges of extreme climate change scenarios must be considered for future management plans and strategies.

THE CAMERON HIGHLANDS – UPPER BASIN SYSTEM

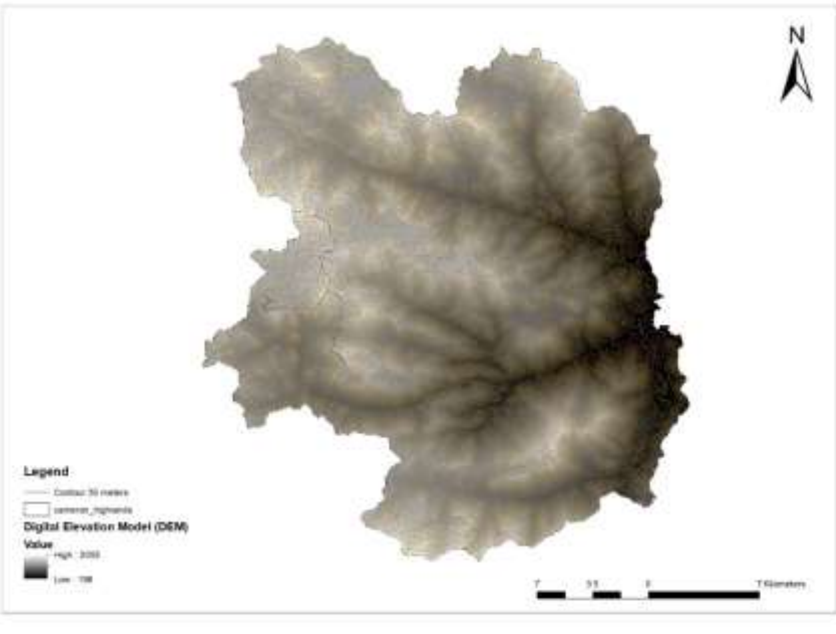

Figure 1: Elevation map of Cameron Highlands

The Cameron Highlands region is a part of the highland plateau and is situated on the eastern side of the main range. Though a plateau, it is highly dissected with hills and valleys in the inner zone while surrounding it is a chain of mountain peaks (Rozimah, 2017). The highest peak is Brinchang Mountain (2031 meters) followed by Beremban Mountain (1840 meters), Jasar Mountain (1704 meters), Siku Mountain (1916 meters) and Cantik Mountain (1802 meters). More than 92% of the study region is located between 1070 meters to 1600 meters above sea level.

The plateau has developed physiographically as a separate unit lying high above the country to the east and west due to its unique characteristics compared to other parts of the main range and has experienced an isolated climate. Like all tropical hilly regions, Cameron Highlands have very high annual rainfall, averaging between 2500 and 3000 mm per year. There are two distinct wet seasons yearly: September to December and February to May. Cameron Highlands experience their highest rainfall between March and May, as well as November and December (Pradhan et al., 2010). The Cameron Highlands has a temperate climate with an average annual temperature of 23°C, facilitating economic growth in the 1970s (Met Malaysia, 2019).

Forest occupied approximately 50778 ha of the Cameron Highland Region, or 72% of the total area. Therefore, 76% of the total forest cover is permanent forest estate (PFE), and the remaining is state land forest. The Cameron highlands consist of thirteen forest reserves covering a total of 38771.68 hectares. Some reserve woods have been designated as hutan lindungan tanah (28,175.60 hectares) and forest catchment areas (1486.00 ha). Tropical forests constitute the region's natural environment as a whole. The distribution of the various forest types is as follows: Lowland Dipterocarp Forest (LDF) and Hill Dipterocarp Forest (HDF) occur at 100 to 300m elevation and 300 to 750m, respectively, such as those contained in forest reserves in Ulu Telom. The Upper Dipterocarp Forest (UDF) occurs at elevations ranging from 750m to 1200m, such as the forest areas at Ringlet. Next is Lower Montane Forest (LMF), occurring at 1200m to 1500m elevation range such as the forested areas close to Brinchang and Tanah Rata towns. Finally, Upper Montane Forest (UMF) occurs at elevations greater than 1500m, such as mountain peaks and ridge tops on Brinchang Mountain, Jasar Mountain, Perdah Mountain and Irau Mountain (Kumaran & Ainuddin, 2006).

The entire region is surrounded by mountains, and a crucial watershed is located within tropical rainforests. The forest captures passing clouds that would otherwise not precipitate, serving as a vital catchment for much of lowland Malaysia (Barrow C.J et al., 2005). The Cameron Highland is located in the Titiwangsa Range and is drained into the Malacca Strait by the Perak River system in the west. In the east, the Cameron Highlands is being drained by the Kelantan and Pahang river systems into the South China Seas (Salleh & Ghaffar, 2010). Cameron Highlands consists of three main rivers: Bertam River, River Telom, and Lemoi River, which flows from north to south. Cameron Highlands is unique in its administrative and physical boundaries that overlap, consisting of 123 tributaries making this area rich in water resources. Seven hydroelectric power stations are located in the main river, and one is under construction. In addition, water resources are also used for domestic supply and to irrigate agricultural areas.

AGRICULTURE PRACTICES IN THE HIGHLAND REGION

The growing world population has a rising demand for crop production; accordingly, global crop demand will increase 100-110% from 2005 to 2050 (Tilman et al., 2011). Agricultural activities in the Cameron Highlands have started since colonial times. The cool climate in Cameron Highlands is very conducive for temperate vegetables such as cabbage and tomatoes.

Hence, vegetable farming became the primary activity and the Chinese became the dominant farmers. The farmers supply good temperate vegetables for European communities. During that time, the area's development is scattered and relatively small. Like highland farmers in many countries, most farmers practice small-scale farming and depend on the weather to irrigate crops. Large farmers only monopolize a systematic irrigation system.

After almost half a century, Cameron Highlands is growing rapidly as Malaysia's main highland agricultural area. Despite its steep and dissected topography, the temperate climate of the Cameron Highlands has enabled it to become a leading producer of fresh vegetable produce in Malaysia. (Aminuddin et al., 2005). Cameron Highlands Region comprises fertile highland soil composition and climate suitable for agriculture. In 2010, almost 9086.28 ha of farmland in Cameron Highland fields produced more than 800 metric tons of vegetables per day. Cabbage, Chinese cabbage, and tomato are three common vegetables in Cameron Highlands. Recently, flower farming has risen, and sometimes flowers are produced at the expense of food. In Cameron Highland, the top three flower species were chrysanthemum (52%), carnation (20%), and rose (18%) (Abdullah et al., 2019)

The predominant forms of agricultural practices in Cameron Highland are terracing, contouring, and sheltered farming. 58% of agricultural methods in Cameron Highland consist of sheltered farming, followed by contouring (27%) and terracing (15%) (Aminuddin et al., 2005). Rain shelters are frequently used to grow high-value vegetables such as tomatoes, lettuce, and strawberries. Rain shelter-grown plants produced significantly heavier fruits than those that did not. The average weight of fruits per plant was more than double that of plants grown in open fields, with larger and more fruits from plants grown in open fields, and the yield per plant was higher than that of plants grown in open fields (Aganon et al., 2002).

THE CLIMATE CHANGE EVENTS AND EFFECTS ON AGRICULTURE

Climate change is any change over time caused by natural variability or anthropogenic activities (IPCC, 2007). This definition differs from that used in the Framework Convention on Climate Change, which defines climate change as a change in climate caused directly or indirectly by human activity that alters the composition of the global atmosphere, in addition to natural climate variability observed over comparable periods (Alley et al., 2002). Numerous indicators indicate that the environment is altering at an alarming rate. The sixth assessment report of the Intergovernmental Panel on Climate Change identifies a rise in the global mean surface temperature (GMST) as one of the defining characteristics of climate change (IPCC, 2021).

According to forecasts of the Intergovernmental Panel on Climate Change (IPCC), the global annual temperature will increase by 1°C by 2025 and by up to 3°C by the end of the 21st century, and greenhouse gas emissions will cause CO2 levels to rise by 445-640 ppm by 2050 (Kumar et al., 2020). If temperatures rise by around 2°C over the next 100 years, the detrimental consequences of global warming will begin to spread to most regions of the planet and directly impact the majority of earth's organisms. In addition to an increase in atmospheric temperature and carbon dioxide, a shift in precipitation patterns, and an extended period of drought, climatic unpredictability has significant implications for the agriculture industry (IPCC, 2021),

Agriculture is one of the sectors most vulnerable to the effects of climate change. However, the high topography is the primary factor that contributes to Cameron Highlands' cool climate, making it an ideal place to cultivate fruits and vegetables. The increase in temperature and the unpredictability of precipitation has had multiple effects on the farming activities of farmers. Cameron Highlands has been Malaysia's leading vegetable supplier for decades, delivering up to 40 percent of the country's crops (Tey et al., 2021). Cameron Highlands produces four of Malaysia's nine major crops in 2021, namely cabbage, eggplant, chili pepper, and tomato (Jabatan Pertanian Semenanjung Malaysia, 2019)

The agricultural sector is highly vulnerable to future climate change scenarios, including an increase in the frequency of extreme weather events and disasters. Temperature and precipitation changes will cause changes in land and water regimes, affecting agricultural productivity (Anwar et al., 2013). Changes in precipitation patterns and rising temperatures would have an impact, either positively or negatively, on the natural resource elements of the agricultural system (Easterling et al., 2007). According to Leff et al. (2004), the inter-annual, monthly and daily distribution of climate variables (e.g., temperature, radiation, precipitation, the water vapor pressure in the air, and wind speed) influences a variety of physical, chemical and biological processes that drive agricultural, forestry and fisheries productivity. The current climatic and atmospheric conditions and photoperiod influence the latitudinal distribution of crops, pasture and forest species. Total seasonal precipitation and its variability pattern are critical for agriculture (Olesen & Bindi, 2002).

Numerous disasters, including landslides, mud floods, rising temperatures, droughts, and rising sea levels, are caused by climate change. Among all these consequences, the increase in ambient temperature has the most significant impact on Cameron highlands. The resulting increase in temperature will reduce the production of highland crops. Additionally, the rise in temperature influences the natural water cycle and the surrounding air pressure. In recent years, Cameron Highlands has had above-average precipitation, resulting in floods and landslides. In addition to affecting the people, the calamity had a massive effect on the agricultural sector. All vegetable and fruit crops in the Cameron Highlands are grown in temperate conditions on lush hillside slopes.

In addition, climate change has also caused an increase in pests in the Cameron Highlands. Temperature rise directly impacts the reproduction, survival, dissemination, and population dynamics of pests, as well as their relationships with their environment and natural adversaries (Prakash et al., 2014). Since temperature is the most influential environmental factor on the population dynamics of insects, it is anticipated that global warming will result in an expansion of their geographic range, an increase in the number of generations, and a decrease in the efficacy of biological control, particularly natural enemies (Mafie, 2022)

As ectothermic species, insects are among the most vulnerable to climate change. As a result, thermal changes have a considerable impact on their development, reproduction, and survival. (Bale et al., 2002). Because insects are involved in numerous biotic interactions, such as with plants, natural enemies, pollinators, and other organisms, which play a significant role in the ecological functioning of insect pests, the effects of climate change on insect pests are of greater significance (Moore et al., 2008). In addition to direct effects on crop productivity, climate change also threatens global food production through pest-related crop losses, according to a recent declaration. Each additional degree of temperature increase could result in an increase of 10-25% in yield losses due to insect pests (Shrestha, 2019).

Crops respond to their environmental conditions with threshold responses that affect their growth development (Porter and Semenov, 2005). Short-term extreme climate events like storms and floods, interannual and decadal climate variations and large-scale circulation changes like the El Nino Southern Oscillation (ENSO) significantly impact agriculture and crop production (Tubiello, 2005). Additionally, the divergent effects of temperature and precipitation changes on spatial and temporal distribution will also affect the growing seasons (Passioura 2002; Anderson 2010).

Crops show different resilience to climate change. In highland areas, most plants are vulnerable to extreme climate change scenarios. This is because the highlands are also exposed to extreme climate events such as floods and mudslides. According to (Fischer et al. 2002), there is also a broad consensus that the water cycle will change and affect rainfall as the earth warms. As a result, extreme climate events will become more frequent.

Changes in the water cycle and weather impact agriculture because most farms are on the hillsides. Heavy and prolonged rainfall will cause the soil structure to loosen and collapse. However, the impact of climate change is another phase that leads to changing rainfall parameters with consequences on soil erosion and sedimentation of the rivers (Nasidi et al., 2021). Therefore, the resilience of temperate crops to climate change has become a significant challenge in Malaysian highlands agriculture practices.

The highland region has been plagued by slope failure and sinkholes (Razali et al., 2018). The average annual rainfall in this area is 2850 mm and is exceptionally high during the northeast monsoon. The combination of heavy rains and rapid urban development has caused soil instability in the area. Furthermore, illegal deforestation has reduced the stability of the hillsides. (Aik et al., 2021).

Farmland is best suited for production between slopes of 15 and 35 degrees. However, Aik et al. (2021) report a continuous rise in farmed land above 35° in Cameron Highlands. As natural disasters become more common, vegetable farms on the hillsides will face destruction from landslides and mudslides, particularly during heavy rains during the northeast monsoon season. Mudslides caused by slope failure will flow downhill, destroying agriculture and settlements. In 2014, a giant mudslide occurred in Bertam Valley, which is one of the largest agricultural areas in Cameron Highlands. The disaster destroyed large agricultural areas and caused property damage and loss of life (Rozimah & Khairulmaini, 2016). After all, climate change in the highlands affects agricultural activities and destroys the ecosystem as a whole in the event of a natural disaster.

CONCLUSION

In general, the effects of global change are likely to impair the productivity of agricultural systems in Cameron Highlands, as rising CO_2 concentrations will immediately raise surrounding temperatures and pest populations. At the same time, climate change increases the frequency of natural disasters in mountainous regions. This will necessitate the modification of current agricultural methods to new climate circumstances.

However, increased carbon has a positive effect on plant growth. Plant response to elevated CO_2 alone, without climate change, and yield will depend on the photosynthetic pathway, species and growth studies confirm that the effects of elevated CO_2 on plant growth are positive.

Highlands are a physical system that is sensitive and fragile to any changes. In addition, an imbalance of input of energy and matter can disrupt the system's dynamic balance. Climate change will cause agricultural activities to be affected in terms of productivity and crop quality. Consequently, the production of moderate-climate vegetables in Cameron Highlands will decline due to climate change and natural disasters. Therefore, continuous research is required to ensure the sustainability of highland agriculture in extreme climate conditions.

REFERENCES

Abdullah, A. F., Aimrun, W., Nasidi, N. M., Hazari, K., Sidek, L. M., & Selamat, Z. (2019). Modelling erosion and landslides induced by farming activities at Hilly Areas, Cameron Highlands, Malaysia. *Jurnal Teknologi*, *81*(6), 195–204. https://doi.org/10.11113/jt.v81.13795

Aganon, C. P., Mateo, L. G., & Cacho, D. (2002). Enhancing off-season production through grafted tomato technology Part of a report on a research project. *Philippine Journal of Crop Science*, *27*(2), 3–9.

Aik, D. H. J., Ismail, M. H., Muharam, F. M., & Alias, M. A. (2021). Evaluating the impacts of land use/land cover changes across topography against land surface temperature in Cameron Highlands. *PLoS ONE*, *16*(5 May), 1–15. https://doi.org/10.1371/journal.pone.0252111

Alley, R., Berntsen, T., Bindoff, N. L., Chen, Z., & Amnat Chidthaisong. (2002). CO2 emission trends in the cement industry: An international comparison. *Mitigation and Adaptation Strategies for Global Change*, *7*(2), 115–133. https://doi.org/10.1023/A:1022857829028

Aminuddin, B. Y., Ghulam, M. H., Abdullah, W. Y. W., Zulkefli, M., & Salama, R. B. (2005). Sustainability of current agricultural practices in the Cameron Highlands, Malaysia. *Water, Air, and Soil Pollution: Focus*, *5*(1–2), 89–101. https://doi.org/10.1007/s11267-005-7405-y

Anderson WK (2010) Closing the gap between actual and potential yield of rainfed wheat. The impacts of environment, management and cultivar. Field Crop Res 116:14–22

Anwar, M. R., Liu, D. L., Macadam, I., & Kelly, G. (2013). Adapting agriculture to climate change: A review. *Theoretical and Applied Climatology*, *113*(1–2), 225–245. https://doi.org/10.1007/s00704-012-0780-1

Bale JSB, Masters GJ, Hodkinson ID, Awmack C and Bezemer TM 2002. Herbivory in global climate change research: Direct effects of rising temperature on insect herbivores. *Global Change Biology*, 8(1):1-16

Barrow C.J, Clifton J., Chan N.W, & Tan Y.L. (2005). Sustainable Development in the Cameron Highlands, Malaysia. *Malaysia Journal of Environmental Managment*, *6*(August), 41–57.

Fischer, G., M. Shah and H. van Velthuizen, 2002a: Climate change and agricultural vulnerability, IIASA Special Report commissioned by the UN for the World Summit on Sustainable Development, Johannesburg 2002. International Institute for Applied Systems Analysis, Laxenburg, Austria, 160 pp.

IPCC. (2007). Climate Change- Impacts, Adaptation and Vulnerability. In Parry ML, Canziani OF, Palutikof JP, van der Linden PJ and Hanson CE (eds.), Cambridge University Press, Cambridge, UK, p. 976.

IPCC. (2021). Climate Change 2021: *The Physical Science Basis*; Intergovernmental Panel on Climate Change: Geneva, Switzerland,

IPCC. (2021). Climate Change 2021: *The Physical Science Basis*; Intergovernmental Panel on Climate Change: Geneva, Switzerland,

Jabatan Pertanian Semenanjung Malaysia. (2019). *Statistik Tanaman Sayur-Sayuran Dan*

Tanaman Ladang Malaysia. 1–215. http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/maklumat_pertanian/perangkaan_tanaman/perangkaan_sayur_tnmn_ladang_2017.pdf

Kumar. K, Bhattacharjee. S, Vaikuntapu, P. R, Sharma, C. L, Jayaswal. D, Sharma. R and Sundaram, R. M. (2020). Climate Change Mitigation and Adaptation Through Biotechnological Interventions. In: Ch. Srinivasarao et al., (Eds). Climate Change and Indian Agriculture: Challenges and Adaptation Strategies, ICAR-National Academy of Agricultural Research Management, Hyderabad, Telangana, India. pp-1-22. Proc

Kumaran, S., & Ainuddin, A. N. (2006). Forests, water and climate of Cameron Highlands. School of Humanities, Universiti Sains Malaysia.

Leff, B., N. Ramankutty and J.A. Foley, 2004: Geographic distribution of major crops across the world. *Global Biogeochem. Cy.*, 18, GB1009.

Mafie, G. K. (2022). The Impact of Climate Change on Agricultural Productivity in Tanzania. In *International Economic Journal* (Vol. 36, Issue 1). https://doi.org/10.1080/10168737.2021.2010229

Malaysia Meteorologi Department.(2021) Cameron Highlands Temperature 2009–2019. Available online: https://www.met.gov.my/ (accessed 30 May 2021)

Mishra, P. K, Rai. A, Rai, S. C. (2020) Land use and land cover change detection using geospatial techniques in the Sikkim Himalaya, India. *The Egyptian Journal of Remote Sensing and Space Science. 23*(2):133–43

Moore JP, et al. (2008) Wine biotechnology in South Africa: towards a systems approach to wine science. *Biotechnol J* 3(11):1355-67

Nasidi, N. M., Wayayok, A., Abdullah, A. F., & Kassim, M. S. M. (2021). Spatio-temporal dynamics of rainfall erosivity due to climate change in Cameron Highlands, Malaysia. *Modeling Earth Systems and Environment*, *7*(3), 1847–1861. https://doi.org/10.1007/s40808-020-00917-4

Olesen, & Bindi. (2002). Consequences of climate change for European agricultural productivity. *Land Use and Policy*, *16*, 239–262. www.elsevier.com/locate/eja

Passioura JB (2002) Environmental biology and crop improvement. Funct Plant Biol 29:537–546

Porter, J.R. and M.A. Semenov, 2005: Crop responses to climatic variation. Philos. T. Royal Soc. B, 360, 2021-2035

Pradhan, B., Sezer, E. A., Gokceoglu, C., & Buchroithner, M. F. (2010). Landslide susceptibility mapping by neuro-fuzzy approach in a landslide-prone area (Cameron Highlands, Malaysia). *IEEE Transactions on Geoscience and Remote Sensing*, *48*(12), 4164–4177. https://doi.org/10.1109/TGRS.2010.2050328

Prakash, K. ; Radhamani, J. ; Pandey, A. ; Yadav, S., 2014. A preliminary investigation of cultivated and wild species of *Luffa* for oil and protein contents. Plant Genetic Resources: Characterization and Utilization, 12 (1): 103-111

Razali A, Ismail SN, Awang S, Praveena SM, Abidin EZ. (2018). Land use change in highland area and its impact on river water quality: a review of case studies in Malaysia. *Ecological processes*. 7(1):1–7.

Rozimah, R., & Khairulmaini, O. S. (2016). Highland Regions – Land use Change Threat and Integrated River Basin Management. *International Journal of Applied Environmental Sciences*, *11*(6), 1509–1521.

Rozimah. R. (2017). Environmental resources developments and degradation issues: towards integrated river basin management (IRBM) of Cameron Highlands, Malaysia (*Unpublished master's thesis). University of Malaya, Malaysia.*

Salleh, K. O., & Ghaffar, F. A. (2010). Upper basin systems : Issues and implications for sustainable development planning in Malaysia. *Journal of Geography and Regional*

Planning, *3*(11), 327–338.
Shrestha, S. (2019). Effects of Climate Change in Agricultural Insect Pest. *Acta Scientific Agriculture*, *3*(12), 74–80. https://doi.org/10.31080/asag.2019.03.0727
Tey, Ruoxi and Choon, Shay Wei and Tan, Siow Hooi (2021) *Adaptation Towards Climate Change Impact Among Farmers in Cameron Highlands.* In: 2nd Post Graduate Social Science Colloquium Proceedings 2021, 8-9 June 2021, Cyberjaya, Malaysia
Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(50), 20260–20264. https://doi.org/10.1073/pnas.1116437108
Tubiello, F.N., 2005: Climate variability and agriculture: perspectives on current and future challenges. Impact of Climate Change, Variability and Weather Fluctuations on Crops and Their Produce Markets, B. Knight, Ed., Impact Reports, Cambridge, UK, 45-63