Climate Change and its Economic Impact on Sustainable Agricultural Production in Malaysia: An aggregate Analysis

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Abstract. Sustainable agricultural production in Malaysia is under climate change's threat. Several climate-driven factors such as heat waves, irregular and excessive rainfall patterns, storms, and floods are the current worries of many farmers in the country and these factors put together put their livelihood in jeopardy. Future predictions indicated a significant further variability in climatic patterns with irregular rainfall. This study aims to investigate the economic impact of climate change on agricultural production in Malaysia by aggregating all agricultural productions over the 1990 – 2021 period. A time series econometric method called autoregressive and distributed lag (ARDL) method was utilised to achieve the study's objective. The result of the study revealed that climate change has statistically significant negative impact on agricultural production in Malaysia. This implies that food production through agricultural production in the country is being adversely affected by climate change. As such, climate change mitigating strategies are strongly recommended with strict implementation to ensure sustainable agricultural production. Other recommendations include the practice of agroforestry, planting of climate resilient plants, crop rotation, and the use of soil smart technology. These actions will assist in minimising the adverse effect of climate change on agricultural production and indirectly boost food production.

1 Introduction

Malaysia's agricultural sector had been the main contributing sector to economic growth before 1970 [1]. However, from 1970 onward, Malaysia has moved from the agriculture sector-based economy to a secondary sector manufacturing sector. In the year 2016, the portion of the agricultural sector's contribution to the Malaysia's gross domestic products (GDP) is 8.1% or RM89.5 billion [2]. In Malaysia's agricultural sector, palm oil, rubber, and other produce contributed 43.1%, 7.1%, and 19.5% to agriculture sector GDP, respectively [2].

Agricultural sector in many countries is susceptible to climate change due to enormous scale of climatic conditions and thus has always resulted to largest economic effects [3]. Crop productivity is highly influenced by changes in environmental factors. These environmental factors majorly include temperature and rainfall. According to researches, rising temperatures have a potential adverse effect on food security, farmers' income, and other factors [4], however rising precipitation levels are expected to neutralise or lessen the negative effects of rising temperatures [5]. Around 80% of the agricultural production requires water and the projection of rainfall changes can influence the direction of climate effect on agricultural production [6].

Agriculture is a third important industry in Malaysia after manufacturing and services. The total workforce in agriculture sector compared to the total workforce in 2017 (6.21%) was higher compared to 2016 (6.16%). According [7], 85% drop in global malnutrition by 2050 was due to rising in incomes in developing countries, and this problem can be overcome if agricultural productivity continues to increase, and climate change is taken into

consideration [8]. Therefore, this study set out to study the economic impact of climate change on agricultural productivity in the context of Malaysia.

Depending on the geography and irrigation technique, different crops are affected differently by climate change. By shortening their growing season, many crops are anticipated to have lower yields ([9], [10], [4]). If both the tropical and temperate regions record a warming of 2°C, it is anticipated that the total production of cereal crops will diminish [11]. Because tropical crops remain closer to their high-temperature optimums and consequently endure high-temperature stress during high temperatures, climate change generally has a higher impact on tropical locations. In the literature, the broad assumption is that temperature variability leads to alterations in the land and water regimes, which can potentially affect agricultural output negatively. Research has also shown that the effects on agricultural productivity are likely to be bad specifically in the tropical regions, where poorest countries are located [12]. Estimates show that global food production is likely to be strong. However, tropical regions are likely see both a drop in agricultural yields and an increase in poverty as many people whose jobs depend on agriculture become more vulnerable to expected climate pressures [13]. Studies indicate that southern Africa countries might lose more than 30 percent of its major crops by 2030 owing to climate change. The losses of regional crops including maze, rice, and millets might exceed 10 percent in South Asia [14].

With a projection of 0.3% annual loss of future global GDP by 2100, crop production lost could drive up food costs and have a detrimental impact on agriculture welfare globally [15]. [16] revealed that although climate change has little impact on the global food supply, poorer nations will suffer from its substantial negative effects. In addition to influencing crop yields and production, climate change also has an impact on the natural resources that are essential to agricultural production, particularly land and water. Climate change is anticipated to decrease the amount of water that is available, while agricultural water use is anticipated to rise by 19% by 2050 [17]. For instance, the increasing dependence by Malaysian farmers on groundwater to deal with climate driven phenomena like drought and other natural disaster like floods and plant diseases has resulted in a significant decline in agriculture production and profitability in Malaysia [18]. Particularly, the farmer's income earning, and profitability of paddy production will decrease climate variation. Climate change also hurts food security as paddy production significantly decreases due to climate change [18].

In South Asia, annual temperature is projected to upsurge by 1.4–1.8 °C in 2030 and 2.1–2.6 °C by the year 2050, and thus increasing the region's heat-stressed areas by 12% in 2030 and 21% in 2050 [19]. However, other than climate change, the agricultural productivity could be influenced by other factors such as, variability, and adaptability and the efficiency of agricultural inputs as well as the prevalence of pests and diseases [14]. Therefore, the ability to adapt to these changes is paramount to the productivity of the sector. The real effects of climate change are highly dependent on the adaptive capacity [20]. Other than that, [13],[14] and [21] found that weather conditions such as excess cold and heat waves can affect agricultural production in countries such as India and Nigeria.

Like many countries, adaptation is important to Malaysian agricultural sector for several reasons including, but not limited to: (i) agriculture is the main source of livelihood and a major contributor to the Malaysian economy; (ii) largely rain-fed, making it prone to extreme climate condition; (iii) surging population as a result of immigration, and economic and income growth has further aggravated the effects of climate change, which is largely due to a simultaneous increase in the demand for water and land from various sectors of the country; (iv) lack of policies and quality institutions to mitigate climate challenges in the sector; and (v) to sustain local food security. Hence, [22] recommended that, other than technological progress and advancement, it is necessary to have institutional reforms to ensure sustainable climate adaptation to mitigate the adverse impact on capital productivity and agricultural productivity by extension.

Apart from that, too much water resulting from a massive flood can also be impacted on food production. Massive flood could wash away entire crops over the colossal size of land. The problem of soil waterlogging caused by excess water can reduce the growth of the plant [23]. Hence, they further added that changes in short-term extreme temperature could be critical. In the case of Zimbabwe, [24] revealed that small holder farmers perceived and projected climate change to have negative effect on their agricultural production by 2050. As such, it can affect sustainability of future agricultural production [25]. In addition, earlier studies have pointed out that the agricultural effects of climate change can result to other socio-economic issues such as unemployment, decreasing household income and welfare, migration, and food insecurity ([18], [25]).

Considering the foregoing review, this study would contribute to the body of literature by focusing on the impact of climate change on total agriculture output in Malaysia. This study would further enrich the existing literature on climate change and agriculture especially in the case of Malaysia. The rest of the paper is organized in sections; two, three, and four for methodology, results, and conclusion, respectively.

2 Methodology and Data

To achieve the objective of the study, we employ production function as a theoretical based to show the relationship between climate change and agricultural productivity. The theoretical specification of production function is as thus:

$$Y_t = f(K_t, L_t) \tag{1}$$

where Y is output, K is capital and L is labour. According to endogenous growth theory, the permanent changes in physical and human investment rate, other policy variables including policy, government and private consumption should lead to permanent changes in economic growth. Moreover, it can be argued that agriculture also accounts for a significant fraction of the economic activity in Malaysia. The idea is based on the fact that agricultural productivity leads to food production and its surplus created in the agriculture sector would create demand for other sectors as well [26]. This study adopts an augmented [21]'s model as thus:

$$A_t = f(Labour_t, Capital_t, Land_t, Rain_t, Tem_t) \tag{2}$$

where A_t is total agricultural output, proxied by agricultural production index, *Capital* is amount of capital investment, *Labour* is number of workers in the agricultural sector, *Land* is measured by total agricultural land area, *Rain* is total annual rainfall and *Tem* is average annual temperature. The data utilised by this research were sourced from World Bank database under World Development Indicators (WDI) for the 1990 – 2021 period.

Furthermore, the current study employed an econometric method called autoregressive and distributed Lag (ARDL) model by [27] for data estimation. ARDL can be applied to the case of variables that consist of mixed orders of integration. To ascertain this, the order of integration was tested using two unit-root tests: (1) augmented Dickey-Fuller (ADF) and (2) Phillips-Perron (PP). Furthermore, the bound test was applied as follows:

$$
\begin{aligned}
\Delta lnA_t = a_0 &+ \sum_{i=1}^{q} a_{yi}\,\Delta lnA_{t-1} + \sum_{i=0}^{q} a_{li}\,\Delta \ln Labour_{t-i} + \sum_{i=0}^{q} a_{ki}\,\Delta lnCapital_{t-1} + \sum_{i=0}^{q} a_{di}\,\Delta \ln Land_{t-i} \\
&+ \sum_{i=0}^{q} a_{ri}\,\Delta \ln Rain_{t-i} + \sum_{i=0}^{q} a_{mi}\,\Delta \ln Tem_{t-i} + a_1 lnA_{t-1} + a_2 \ln Labour_{t-1} \\
&+ a_3 \ln Capital_{t-1} + a_4 \ln Land_{t-1} + a_5 \ln Rain_{t-1} + a_6 \ln Tem_{t-1} + \varepsilon_t
\end{aligned} \tag{3}
$$

This model represents the ARDL estimation of the effect of climate change on total agricultural output in Malaysia. This study then checked the cointegration relationship among the modelled variables using the hypothesis: $a_1 \neq a_2 \neq a_3 \neq a_4 \neq a_5 \neq a_6 \neq 0$. Furthermore, we estimate the short-run dynamism among the modelled variables using the following model:

$$
\begin{aligned}
\Delta lnA_t = a_0 &+ \sum_{i=1}^{q} a_{yi}\,\Delta lnA_{t-1} + \sum_{i=0}^{q} a_{li}\,\Delta \ln Labour_{t-i} + \sum_{i=0}^{q} a_{ki}\,\Delta lnCapital_{t-1} + \sum_{i=0}^{q} a_{di}\,\Delta \ln Land_{t-i} \\
&+ \sum_{i=0}^{q} a_{ri}\,\Delta \ln Rain_{t-i} + \sum_{i=0}^{q} a_{mi}\,\Delta \ln Tem_{t-i} + a_1 ECT_{t-1} + \varepsilon_t
\end{aligned} \tag{3}
$$

In equation (3), ECT_{t-1} is the error correction term which shows the long-run convergence of the variables such that the error term is negatively significant, and it is $0 < ECT_{t-1} < 1$.

3 Results and Discussion

The estimated results of the impacts of climate change on agricultural output in Malaysia for the 1990–2021 period is presented and discussed in this section. The first estimation step starts by choosing a suitable lag length. Table 1 shows the results of various selection criteria, and the Schwarz Information Criterion (SIC) was used to determine the ideal

lag length. This test begins by calculating the F-statistics and comparing the outcome with the critical value [28]. The F-statistic value of 7.631 is sufficiently greater than the 5 or 1 percent critical value of the upper bound $I(1)$. Furthermore, our study suggests cointegration among the modelled variables at a 1% significant level. Therefore, we can safely infer the existence of long-run relationship among the variables in the model. This implies that there is a co-integrating relationship between agricultural output and its determinants; rainfall, temperature, labour, capital, and land size in Malaysia.

Table 1. The Results of Bound Tests

	F-statistic	Optimal lag length	Level of Sig.	Critical values	
k=5				$I(0)$	$I(1)$
Agricultural Output	7.631***	(3, 0, 2, 2, 1, 0)	10%	2.331	3.417
			5%	2.804	4.013
			1%	3.900	5.419

Note: *, ** and *** indicate significance at 10% level, 5% level and 1% levels, respectively. Sig. stands for significance.

This study further estimated the long-and short-run dynamism among the modelled variables and presented in Table 2. It suggests that climate change significantly impacts agricultural output in Malaysia. However, this impact is minimal, as the results indicate that the slight change in the average annual temperature in Malaysia will have a significant impact on the Malaysian agricultural sector in the long run. Specifically, the results reveal that a 1% rise in the average temperature will lead to about a 0.13% decline in agricultural output in the long run. On the other hand, in the short run, a percentage increase in average temperature will reduce agricultural output by 0.8%. This finding is in tandem with [29] and [30].

Typically, climate is crucial to plant development and growth. Moisture enhances seed germination, with emergence time dependent on temperature. The growth rates of leaves, stems, and roots are determined by the rate of photosynthesis through light. The detrimental impact of climate on agricultural output was also stressed by [14] and [31]. They suggest that an increase in the average temperature can shorten the duration of many crops, thereby decreasing their yield. [31] further posits that climate change also significantly affects the efficiency of agricultural inputs as well as the prevalence of diseases and pests. This outcome was also stressed by [32]. They found that in the United States, crop output improves to 29ºC for maize, 3ºC for soybeans, and 32ºC for cotton. However, yields significantly decline ᵗ any temperature beyond 29ºC.

Although the findings of our study indicate that the negative effect which climate change has on agricultural output may significantly decrease in the long run, this is mostly attributed to various forms of adaptability and interventions. However, these actions are not sufficient to completely curb the effect of climate change on agriculture. For example, global temperature's mean has risen 0.6–1.2ºF over the previous 13 decades (0.3–0.7ºC), and it is predicted that future average global temperature increases may occur at a rate of 0.4 degrees Fahrenheit (0.2 degrees Celsius) every decade. Plant and microbe species may not have sufficient time to adapt to the new environment, which may lead to the extinction of various species. Changes in the past occurred at relatively slower rates, so they were dispersed over time, which provided ample time for most species to adjust to the new climate [14].

A rise in rainfall in Malaysia will result to a rise in total agricultural output in the long run. This shows that rainfall is important for most agricultural products. The cultivation of certain agricultural products, such as vegetables, fruits, and paddy, requires a large amount of water; hence, rainfall is significant for their cultivation. The impact of rainfall on agricultural output is positive and significant in the long-run. Interestingly, this impact is the same as in the short run.

Water is crucial in promoting growth of plants, so rainfall patterns have been confirmed to significantly increase agricultural output. Since more than 80% of all agriculture depends on rain water. Our results indicate that an increase in rainfall in Malaysia will increase total agricultural output in the long-run. Similarly, [31] found that agricultural output increases as rainfall increases and declines as rainfall reduces in the dry season, and vice versa. However, several previous reports reported a negative relationship between total rainfall and agricultural output. The authors suggest that heavy or excessive rainfall that results in floods can destroy entire fields of crops, and excess water can also result in soil waterlogging and stunted plant development [33].

The results further revealed that land area is highly significant and enhances agricultural output in Malaysia in both long-and short-run. Land area is a prime input in agriculture. In general, agricultural land area has a positive long-term and short-term impact on agricultural production. These findings imply that, in the long run, availability and access to sufficient land area will be key determinants of agricultural output in Malaysia, implying that the sector stands to gain from the large size of the land area. This finding is in tandem with Fischer et al. (2005), who suggested

that Russia stands to benefit from the availability of land area, with an estimate of over 245 million hectares for agriculture by the 2080s. This is expected to increase agricultural output by 64% [14]. Additionally, [31] found that an increase in land size led to more than proportionate increases in agricultural output in Vietnam.

On the other hand, the increase in the labour force will lead to rise in total agricultural output in the long-run, although it has been established that increasing labour, especially in the short run, will decrease the productivity of the sector. This is because, given a limited area of agricultural land, when the increase in the labour force is greater than the maximum carrying capacity, it will lead to a reduction in agricultural productivity. This could be affected by various factors, such as the limited space of agricultural land, technological change, the workers' skills, and managerial quality or strategy. When the increase in the labour force is greater than the maximum carrying capacity of the industry or farmland, for instance, it will lead to a decrease in the agricultural productivity. Similarly, the skills of the workers could significantly affect productivity. For example, when there is a major structural or technological change, it is expected that the workers are skilled and can easily transfer their skills from one technological state to another, thereby increasing labour productivity and, consequently, total agricultural output.

For capital, if capital increases, it will lead to a rise in total agricultural output as it enters the model with significant positive sign. By adopting new and advanced equipment, the time for harvesting can be reduced, which, in the end, would result in higher output within a given time frame. However, like labour, the productivity of capital is also important for the desired output. The productivity of capital could be influenced by other factors such as weather, climate, variability, and adaptability [14]. Hence, [22] recommended that, other than technological progress and advancement, it is necessary to have institutional reforms to ensure sustainable climate adaptation to mitigate the adverse impact on capital productivity and agricultural productivity by extension.

**Table 2.** The Results of the Estimated Long-Run and Short Models

Variables	Coefficients
Long run	
$Labour\ Input_t$	.7351***
$Capital\ Input_t$	0.9674***
$Land\ Area_t$	1.8919***
$Rainfall_t$	0.3952*
$Temperature_t$	-0.1272**
Constant, a_0	-8.3162
Short run	
$\Delta Agriculture\ Production\ Index_{t-1}$	-0.4771***
$\Delta Agriculture\ Production\ Index_{t-1}$	-0.2353**
$\Delta Capital_t$	0.2303
$\Delta Capital_{t-1}$	-0.3533**
$\Delta Land\ Area_t$	2.6153***
$\Delta Land\ Area_{t-1}$	0.9705**
$\Delta Rainfall_t$	0.1156**
$\Delta Temperature_t$	-0.7912*
ECT_{t-1}	-0.7153***

Note: *, ** and *** indicate significance at 10% level, 5% level and 1% levels, respectively.

Various diagnostic checks were employed to ensure the robustness of the estimated ARDL models as can be seen in Table 3. The results of these diagnostic tests show that the models passed majority of the tests, including serial correlation, normality, misspecification error using the Ramsey RESET test, and heteroscedasticity. Furthermore, to ascertain how stable the ARDL models are, CUSUM and CUSUM-squared tests suggested by [34] were applied. The CUSUM and CUSUM-squared tests' results show that the models are stable. The models are considered stable since the CUSUM and CUSUM-Square fall with the boundaries.

Table 3. The Results of the Diagnostic Tests

Diagnostic test	F-statistics
Normality	0.9812
Serial Correlation	3.2271
Heteroskedasticity	13.9372
Ramsey RESET	0.4319
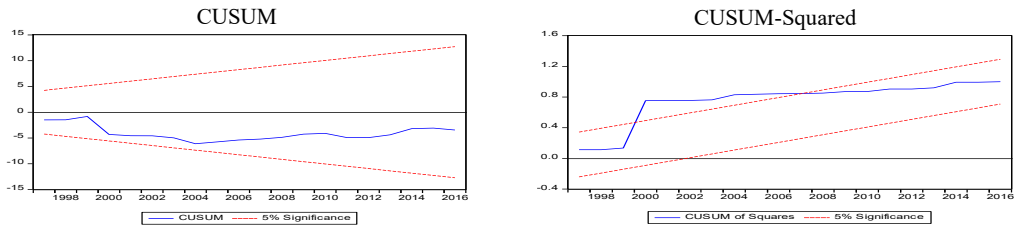
Figure 1. Stability test.

4 Conclusions and Policy Recommendations

The current research examined the effect of climate change on Malaysia's agricultural output from 1990 to 2021. ARDL method was utilised to achieve the objective of the study. The results established a cointegrating relationship among agricultural output, temperature, capital rainfall, labour, and land size. This implies that these variables are significant determinants of agricultural output in Malaysia. The results further revealed that labour has significant positive impact on agricultural output only in the long run, whereas land size and rainfall have positive long- and short-run effects. Conversely, capital has a long-run positive effect on agricultural output. This effect is, however, negative in the short run.

Specifically, climate change in Malaysia has a significant impact on output, as temperature and harsh weather conditions would cause a decline in the production of various agricultural products. In addition, output will increase with consistent rainfall. This is because an increase in rainfall will increase the yield of various agricultural products.

Considering these findings, we recommend that the government of Malaysia should implement new regulations and cutting-edge technology for precise weather forecasting. In addition to focusing on agricultural technology, it is essential to explore how to bring about the necessary institutional quality improvement. Strong commitment and actions are also required to create and support a better irrigation system and empower small-tier farmers. This may result in climate adaptation and a general improvement in crop yield. To combat upcoming climate change, agricultural construction must also be enhanced, and more green development projects should be carried out in Malaysia. With more green development projects, the issue of adverse climate can be reduced and, in the end, avoided. It is also important for policymakers to take control of the country's emissions level. It is essential to make sure that the average country temperature is between 24 °C and 28 °C, or level, given the importance of agriculture to the peoples' welfare.

Acknowledgement

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