UNIVERSITI PUTRA MALAYSIA

IMPACT OF CLIMATE CHANGE AND MACROECONOMIC FACTORS ON MALAYSIAN AGRICULTURE PRODUCTION

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By

ENTEZARI AHMAD FAWAD

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

IMPACT OF CLIMATE CHANGE AND MACROECONOMIC FACTORS ON MALAYSIAN AGRICULTURE PRODUCTION

By

ENTEZARI AHMAD FAWAD

October 2020

Chairman : Kelly Wong Kai Seng, PhD
Faculty : Agriculture

Agriculture sector is one of the important sectors that contributed 8.6% of the national Gross Domestic Product and about 12.1% of the total labour force in 2016. In general, the production system in agriculture sector is totally different from other economic sectors such as manufacturing and services. This is because agricultural production is not just based on labour and capital, but it is also highly related to the climate variables i.e., rainfall, temperature. Therefore, the agriculture sector, especially crop production is affected biophysically by climatic variables such as temperature and rainfall. Past studies have indeed proven and demonstrated the negative effect of climate change on agricultural production. This indicates that climate change reduces agricultural production and consequently, endangering food security. In Malaysia, temperature has increasing trend and rainfall showed acute fluctuations. Prolong raised temperature and rainfall fluctuations cause climate disasters such as flood and drought which lead to declining in agricultural production. In addition to this, the agriculture production is also constrained by the economic factors. For instance, the agriculture employment in Malaysia recorded substantial declines in the years of 1982, 1997, 2001, 2011 and 2016, corresponding with the decline in agriculture gross domestic product growth. However, the effect of climate variables is not considered in the agricultural production function in majority of the past studies. Thus, this study included the climate variables (rainfall and temperature) in to the production function with macroeconomic factors to examine the impact of climate change and macroeconomic factors on the Malaysia's agricultural production. This study employed the cointegration method and utilized annual data spanning a period of 37 years (1980 - 2016) including agriculture real gross domestic product as dependent variable, proxy for agriculture production, while explanatory variables are interest rate, number of employees in agriculture, real gross domestic product per capita as economic factors and rainfall and temperature as climate factors. This study employed cointegration method using Ordinary Least Square technique to

estimate the long run and short run effects with Engle-Granger cointegration test and Error Correction Model, respectively. The cointegration test showed that there is a long-run cointegration between agriculture production and all explanatory variables. In the long run, interest rate, rainfall and temperature have negative and significant effects on agriculture production, while national income and employment have positive significant effects. In the short run, rainfall and temperature have negative and significant effects on agricultural production while employment has a positive and significant effect. Meanwhile, interest rate and income do not have significant effects on agriculture production in the short run. Therefore, the findings of the study highlighted that perfect information sharing of an accurate forecast on weather change, such as rainfall and temperature, is important to reduce the farmers' losses. Based on accurate weather forecast from meteorology department, farmers can make a good plan on how to manage their agricultural production. In the economic perspective, the policy maker can establish special interest loan facilities to encourage farmers increase their investment on their agricultural production and adopt advance technology. Additionally, the authorities should make sure that there is no labour shortage in this sector. Because this is an upstream sector for food production, labour shortage in this sector may cause food shortage. This points to the possible implications of labour shortage in challenging the national food security issue.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN PERUBAHAN IKLIM DAN FAKTOR MAKROEKONOMI TERHADAP PENGELUARAN PERTANIAN MALAYSIA

Oleh

ENTEZARI AHMAD FAWAD

Oktober 2020

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Pertanian merupakan salah satu sektor utama yang menyumbangkan 8.6% kepada Keluaran Dalam Negara Kasar dan sebanyak 12.1% daripada jumlah tenaga kerja pada tahun 2016. Secara umumnya, sistem pengeluaran dalam sektor pertanian adalah berbeza sama sekali daripada sektor ekonomi lain seperti pembuatan dan perkhidmatan. Ini adalah kerana pengeluaran pertanian bukan sahaja berdasarkan tenaga kerja dan modal, tetapi juga sangat berkait rapat dengan pembolehubah iklim seperti hujan dan suhu. Oleh itu, sektor pertanian terutamanya pengeluaran tanaman dipengaruhi secara biofisik oleh pembolehubah iklim seperti suhu dan hujan. Kajian terdahulu telah ternyata menunjukkan kesan negatif oleh perubahan iklim terhadap pengeluaran pertanian. Ini menunjukkan bahawa perubahan iklim mengurangkan pengeluaran pertanian dan seterusnya mengancam keselamatan makanan. Di Malaysia, suhu mempunyai tren yang meningkat dan hujan menunjukkan turun naik yang akut. Kenaikan suhu yang berpanjangan dan hujan turun naik menyebabkan bencana seperti banjir dan kemarau yang menyebabkan penurunan dalam pengeluaran pertanian. Di samping itu, pengeluaran pertanian juga dikekang oleh faktor ekonomi. Contohnya, pekerjaan pertanian mencatatkan penurunan yang besar pada tahun 1982, 1997, 2001, 2011 dan 2016, sejajar dengan penurunan dalam pertumbuhan keluaran dalam negara kasar pertanian. Namun demikian, kesan pembolehubah iklim tidak dipertimbangkan dalam fungsi pengeluaran pertanian dalam kebanyakan kajian lepas. Oleh itu, kajian ini mengambil kira pembolehubah iklim (hujan dan suhu) dalam fungsi pengeluaran bersama dengan faktor ekonomi untuk mengkaji kesan perubahan iklim dan faktor ekonomi terhadap pengeluaran pertanian Malaysia. Kajian ini menggunakan kaedah kointegrasi dan data tahunan yang merangkumi jangka masa 37 tahun (1980 – 2016) termasuk keluaran dalam negara kasar benar pertanian sebagai pembolehubah bersandar, proksi kepada pengeluaran pertanian, sementara pembolehubah penerang adalah kadar bunga, bilangan pekerja dalam pertanian, keluaran dalam negara kasar benar per kapita sebagai faktor ekonomi serta hujan

dan suhu sebagai faktor iklim. Kajian ini menggunakan kaedah kointegrasi dengan teknik kaedah biasa kuasa dua terkecil untuk menganggar kesan jangka panjang dan jangka pendek masing-masing menggunakan ujian kointegrasi Engle-Granger dan model pembetulan ralat. Ujian kointegrasi menunjukkan bahawa terdapat kointegrasi dalam jangka panjang antara pengeluaran pertanian dengan semua pembolehubah penerang. Dalam jangka panjang, kadar bunga, hujan dan suhu mempunyai kesan negatif dan signifikan terhadap pengeluaran pertanian, sementara pendapatan negara dan pekerjaan mempunyai kesan positif yang signifikan. Dalam jangka pendek, hujan dan suhu mempunyai kesan negatif dan signifikan terhadap pengeluaran pertanian sementara pekerjaan mempunyai kesan yang positif dan signifikan. Sementara itu, kadar bunga dan pendapatan tidak mempunyai kesan yang signifikan terhadap pengeluaran pertanian dalam jangka pendek. Oleh itu, hasil penemuan menunjukkan bahawa perkongsian maklumat yang sempurna dalam ramalan perubahan cuaca yang tepat seperti hujan dan suhu adalah amat penting untuk mengurangkan kerugian petani. Berdasarkan maklumat ramalan cuaca yang tepat daripada jabatan meteorologi, petani dapat membuat perancangan yang baik dalam pengurusan pengeluaran pertanian. Dari perspektif ekonomi, pembuat polisi boleh mewujudkan kemudahan pinjaman bunga khas untuk mendorong petani meningkatkan pelaburan mereka dalam pengeluaran pertanian dan menggunakan teknologi canggih. Selain itu, pihak berkuasa harus memastikan bahawa tiada kekurangan tenaga kerja dalam sektor ini. Oleh kerana ini merupakan sektor hulu untuk pengeluaran makanan, kekurangan pekerja dalam sektor ini akan menyebabkan kekurangan makanan. Ini menunjukkan kemungkinan implikasi kekurangan pekerja dalam isu cabaran keselamatan makanan negara.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 08 July 2021

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey Fuller
AGRI	Agriculture Real GDP
BLUE	Best Linear Unbiased Estimator
C-D	Cobb-Douglas
CEMD	Conservation and Environmental Management Division
CO_2	Carbon Dioxide Emission
COP	Crude Oil Price
CUSUM	Cumulative Sum Control Chart
CUSUMSQ	Cumulative Sum Square Control Chart
CVI	Coastal Vulnerability Index
DOSM	Department of Statistics Malaysia
DUM	Dummy Variable
ECM	Error Correction Model
ECT	Error Correction Term
EG	Engle-Granger
EMP	Employment in Malaysia's Agriculture Sector
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
INC	Initial National Communication
INT	Interest Rate
IPCC	Intergovernmental Panel on Climate Change
LM-test	Lagrange multiplier test
LS	Least Square
MARDI	Malaysian Agricultural Research Institute
mm	Millimeter

MNRE	Ministry of National Resource Environment
MOSTE	Ministry of Science, Technology and Environment
OLS	Ordinary Least Square
PP	Philips Perron
RAIN	Average Rainfall
RGDPPC	Real Gross Domestic Product Per Capita
RM	Ringgit Malaysia
sq. km	Square Kilometer
TEMP	Average Temperature
UNFCC	United Nations Framework Convention on Climate Change
WDI	World Development Indicators

CHAPTER 1

INTRODUCTION

This chapter overviews the background of the agricultural industry and climate change variables in Malaysia. To be specific, this chapter also attempts to highlight the effects of climate change on Malaysia's agricultural production and climate change policies in Malaysia and also discuss the issues about Malaysia's agricultural production in the problem statement section. The research question and objectives of the study are developed based on the research issues. Finally, the last section of this chapter elaborates on the contribution and significance of this study.

1.1 Background of the Study

In Malaysia, the agricultural sector contributed 8.6% of the national Gross Domestic Product (GDP) and about 12.1% of the total labour force in 2016. However, the contribution of this sector in national GDP has gradually declined from 23.03% in 1980 to about 15.22% and 10.09% in 1990 and 2010, respectively. On the other hand, employment in this sector has declined from about 1.78 million in 1980 to 1.42 million in 2011. Even the percentage of agricultural contribution to national income and the percentage share of total employment have declined. Regardless, the agriculture sector remains a crucial sector in economic growth and it has become a significant contributor to the Malaysian GDP (Ahmed et al., 2016; Akhtar et al., 2019; Kadir and Tunggal, 2015). Besides, agricultural production is strongly associated with food production as well as an upstream industry to support the food supply.

1.1.1 Malaysia's Agricultural Production

The agriculture sector is one of the important sectors and it is the backbone of Malaysia's economy. Malaysia's agriculture Gross Domestic Product (GDP) showed an increasing trend from 1980 to 2016 (Table 1.1). Compared to 1980, the agriculture GDP has increased for about RM 47,989 million and achieved RM 89,509 million in 2016. Between 1992 to 1995, Malaysia's agriculture GDP has dropped by about 7% from RM 61,485 million to RM 56,946 million. The second downturn of Malaysia's agriculture sector was in the period of 2007 to 2009. Due to the global food crisis and oil price shock effect, Malaysia's agriculture GDP has dropped from about RM 83,630 million in 2007 to RM 72,452 million in 2009.

Even though, after the recession in 2007 due to global food crisis the Malaysia's agriculture recovered until 2010, but the agricultural growth rate drastically decreased after the year 2010 and finally, in 2016, the situation got worst in which the agriculture GDP recorded negative growth. Ultimately, this situation sends a

warning to the country to look back at the policy to increase agricultural production.

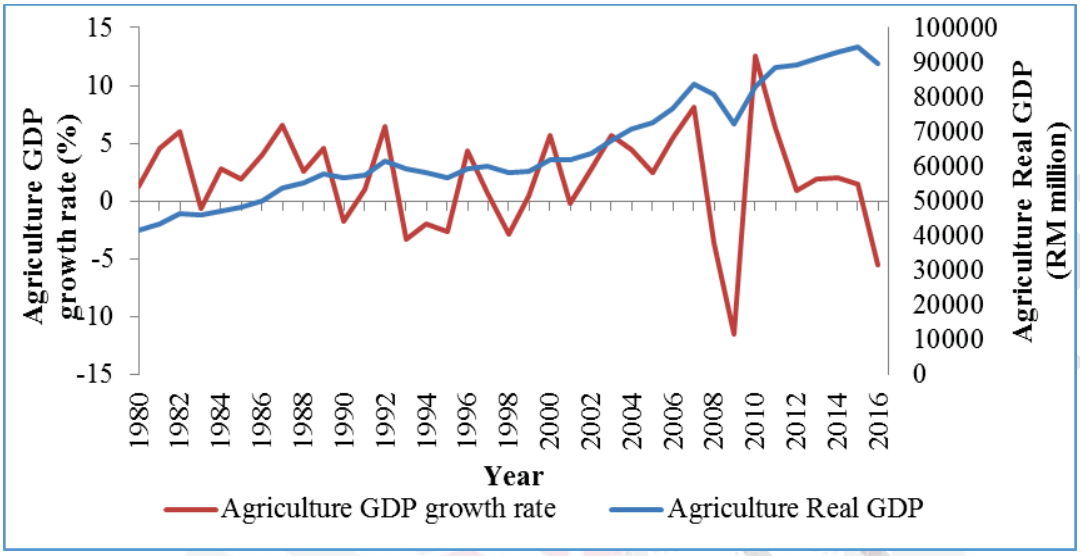

Figure 1.1 : Malaysia's Agriculture Real GDP (million Ringgit) and Agriculture Real GDP Growth Rate (%), 1980 – 2016
(Source: Department of Statistics Malaysia (DOSM), 2019)

Table 1.1 : Agriculture Real GDP (million Ringgit) and Agriculture Real GDP Growth rate (%) in Malaysia, 1980 – 2016

Year	Agriculture GDP	Agriculture GDP Growth Rate	Year	Agriculture GDP	Agriculture GDP Growth Rate
1980	41520.234	1.266	**1999**	58550.353	0.477
1981	43537.362	4.633	**2000**	62097.447	5.712
1982	46353.192	6.075	**2001**	61990.057	-0.173
1983	46055.714	-0.646	**2002**	63767.049	2.787
1984	47363.792	2.762	**2003**	67612.807	5.688
1985	48305.117	1.949	**2004**	70773.704	4.466
1986	50318.171	4.001	**2005**	72609.456	2.528
1987	53855.276	6.568	**2006**	76846.840	5.514
1988	55316.040	2.641	**2007**	83629.946	8.111
1989	57948.078	4.542	**2008**	80749.415	-3.567
1990	56946.507	-1.759	**2009**	72451.749	-11.453
1991	57538.795	1.029	**2010**	82882.000	12.584
1992	61485.190	6.418	**2011**	88555.000	6.406
1993	59555.252	-3.241	**2012**	89406.000	0.952
1994	58427.232	-1.931	**2013**	91181.000	1.947
1995	56946.507	-2.600	**2014**	93048.000	2.006
1996	59528.634	4.338	**2015**	94396.000	1.428
1997	59927.927	0.666	**2016**	89509.000	-5.460
1998	58270.842	-2.844			

(Source: Department of Statistics Malaysia (DOSM), 2019)

Table 1.2 shows Malaysia's agriculture real GDP per capita and agriculture real GDP percentage share in total GDP from 1980 to 2016. The agriculture real GDP per capita shows a decreasing trend which declined from about RM 3,009.13 in 1980 to about RM 2,917.05 in 2016. This indicates that the contribution per person from the agriculture sector has declined. The contribution per person from agriculture dropped about 19.19% from 1992 to 2001. Both the shock from oil price and the global food crisis further caused a substantial decline in agriculture production from 2007 to 2009, and consequently, the decline in agriculture GDP per capita by 16.54% from RM 3,129.82 to RM 2,612.28.

Also, the trend of agriculture GDP % share in total GDP shows a drastic decrease from 1980 to 2016, with the contribution from agriculture sector for about 23.03% of total GDP in 1980 to 8.65% in 2016. This indicates the lack of emphasis in Malaysia's economy on agriculture as the country undergoes transformation and a shift from agriculture to SMEs and manufacturing industries.

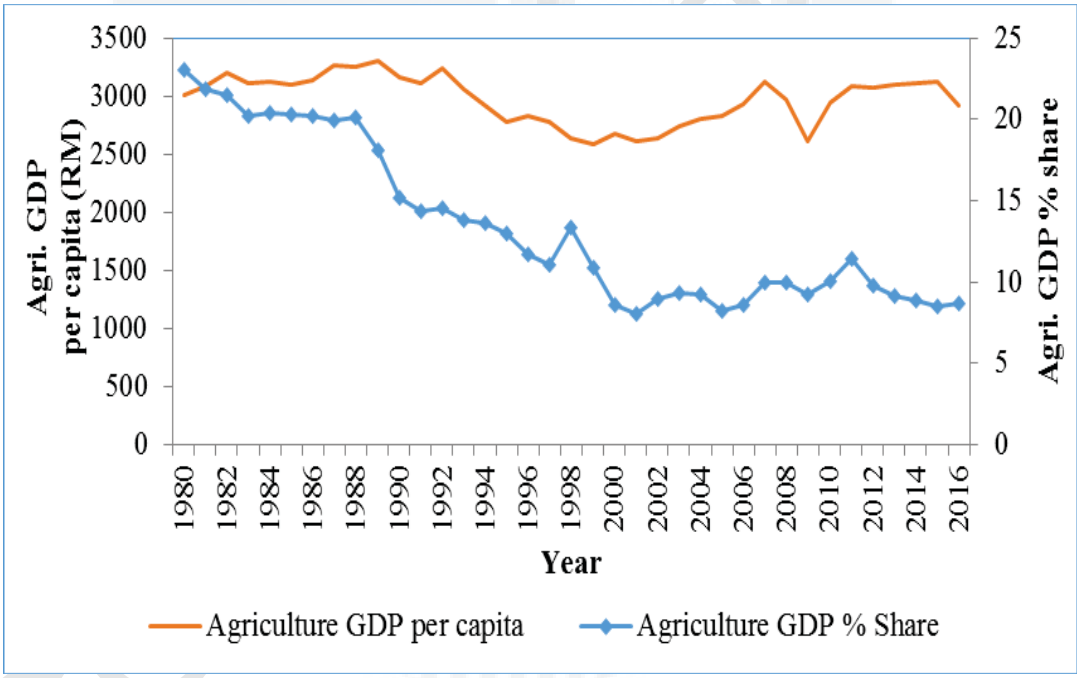

Figure 1.2 : Malaysia's Agriculture GDP % Share and Agriculture GDP per Capita, 1980 – 2016
(Source: Bank Negara Malaysia's Monthly Statistical Bulletin, 2019)

Table 1.2 : Agriculture GDP per capita (RM) and Agriculture GDP % Share in Total GDP in Malaysia, 1980 – 2016

Year	Agriculture GDP per capita (RM)	Agriculture GDP % Share	Year	Agriculture GDP per capita (RM)	Agriculture GDP % share
1980	3,009.130	23.027	**1999**	2583.716	10.842
1981	3,080.316	21.821	**2000**	2677.277	8.599
1982	3,203.132	21.502	**2001**	2614.608	8.011
1983	3,107.794	20.223	**2002**	2634.089	8.985
1984	3,117.619	20.346	**2003**	2737.492	9.306
1985	3,096.695	20.281	**2004**	2809.523	9.271
1986	3,136.314	20.185	**2005**	2826.303	8.262
1987	3,259.610	19.961	**2006**	2932.866	8.610
1988	3,249.591	20.071	**2007**	3129.820	9.987
1989	3,305.848	18.082	**2008**	2964.804	9.969
1990	3,158.462	15.217	**2009**	2612.282	9.219
1991	3,106.857	14.356	**2010**	2938.241	10.090
1992	3,235.610	14.573	**2011**	3090.822	11.453
1993	3,056.483	13.787	**2012**	3075.737	9.794
1994	2,924.652	13.661	**2013**	3094.146	9.113
1995	2,779.559	12.950	**2014**	3115.458	8.873
1996	2,832.321	11.680	**2015**	3118.368	8.470
1997	2,779.228	11.102	**2016**	2917.046	8.654
1998	2,634.943	13.313			

(Source: Bank Negara Malaysia's Monthly Statistical Bulletin, 2019)

1.1.2 Agriculture Productivity

Productivity is defined as a physical relationship between output and input which gives rise to that output (Saxon, 1965). In general, the concept of agriculture productivity is defined as output per unit of input. In another word, the relationship between agricultural output and one of the major inputs such as land, labour and capital, other complementary factors remaining the same (Dewett and Singh, 1966).

Table 1.3 shows the agricultural productivity (Agriculture GDP per hectare) in Malaysia from 1980 to 2016. The average agricultural productivity from 1980 to 2016 was RM 9459.932 ha^{-1}. The agriculture productivity showed a constant growth before the year 2000 and the average growth rate was 0.197% per year. However, it shows an increasing trend from 2000 to 2011 with an average growth rate of about 3.68% per year. After 2011, Malaysia's agriculture productivity showed a slight decrease.

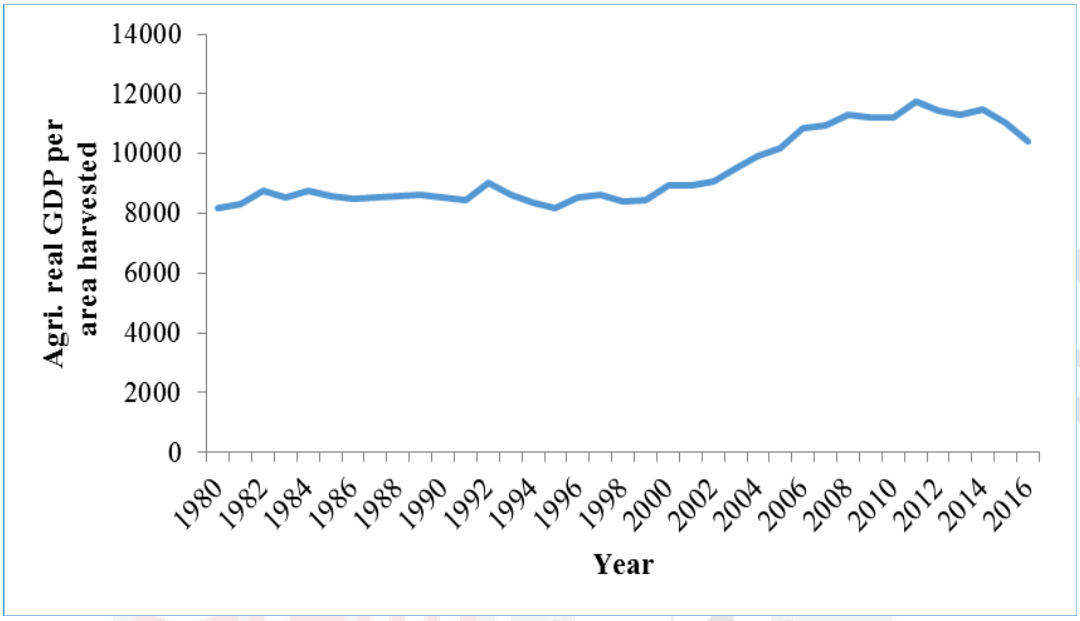

Figure 1.3 : Malaysia's Agriculture Productivity (Agriculture GDP per Hectare), 1980 – 2016
(Source: Department of Statistics Malaysia (DOSM) and Food and Agriculture Organization (FAO), 2019)

Table 1.3 : Agriculture Productivity (Agriculture GDP per Hectare) in Malaysia, 1980 – 2016

Year	Agriculture Productivity	Year	Agriculture Productivity	Year	Agriculture Productivity
1980	8182.922	**1993**	8641.990	**2006**	10862.073
1981	8310.623	**1994**	8358.102	**2007**	10962.171
1982	8752.817	**1995**	8175.878	**2008**	11313.799
1983	8520.020	**1996**	8551.635	**2009**	11210.781
1984	8744.066	**1997**	8612.447	**2010**	11216.489
1985	8589.128	**1998**	8391.184	**2011**	11759.355
1986	8471.317	**1999**	8428.521	**2012**	11419.558
1987	8539.077	**2000**	8949.959	**2013**	11313.762
1988	8564.621	**2001**	8923.807	**2014**	11503.029
1989	8621.550	**2002**	9061.567	**2015**	11014.741
1990	8524.318	**2003**	9501.754	**2016**	10419.291
1991	8468.933	**2004**	9924.400		
1992	9033.834	**2005**	10177.955		

(Source: Department of Statistics Malaysia (DOSM) and Food and Agriculture Organization (FAO), 2019)

1.1.3 Agriculture Land Use in Malaysia

The agricultural land area in Malaysia has rapidly expanded from 1980 to 1989 but has a slow growth from 1990 until 2015 (Table 1.4). Malaysia has about 328,550 km^2 total land area in 2016 (Tang, 2019). As recorded, Malaysia's agricultural land has expanded from 49,617 km^2 (about 15.1% of total land area) in 1980 to 78,390 km^2 (about 23.86% of total land area) in 2015. Between the period of 1990 to 2002, there was no expansion of agricultural land in Malaysia, presumably due to the transformation from agricultural-based economies to manufacturing-based economies.

After the year 2002, Malaysia's agricultural land has expanded slowly due to the competition from other sectors such as property and construction. From the year 2009 to 2013, the agricultural land in Malaysia has increased about 1,276.2 km^2 per year. However, there are no changes in Malaysia's agricultural land during the period of 2013 to 2016.

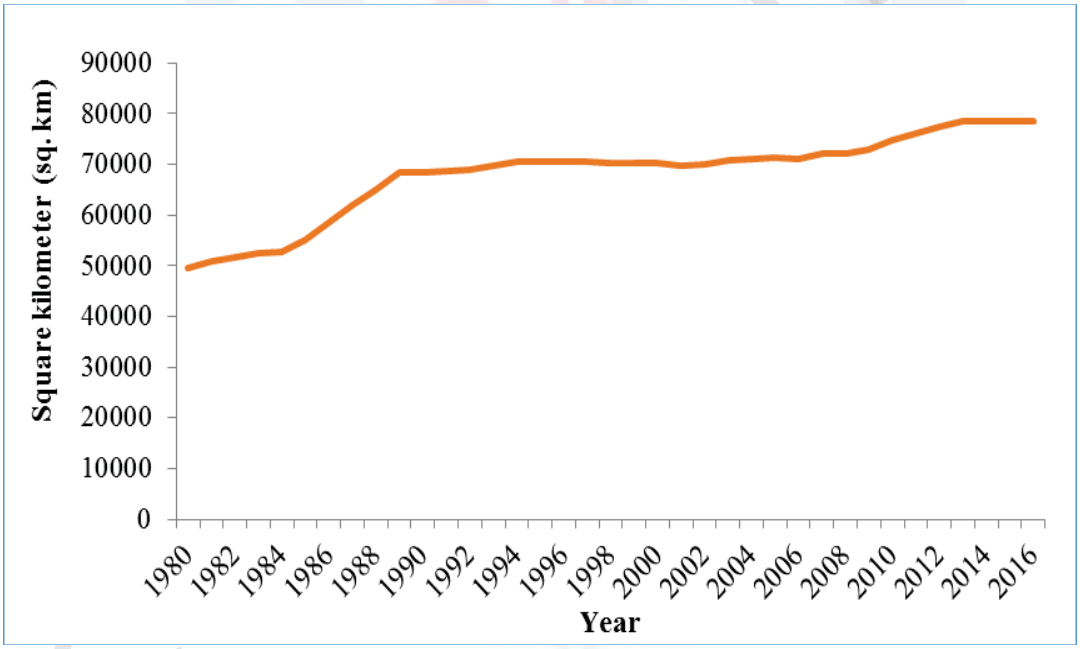

Figure 1.4 : Malaysia's Agriculture Land Use (sq. km), 1980 – 2016
(Source: Food and Agriculture Organization (FAO), 2019)

Table 1.4 : Agriculture Land Use (sq.km) in Malaysia, 1980 – 2016

Year	Agriculture Land Use (sq.km)	Year	Agriculture Land Use (sq.km)	Year	Agriculture Land Use (sq.km)
1980	49617	**1993**	69787	**2006**	71117
1981	51010	**1994**	70613	**2007**	72155
1982	51614	**1995**	70517	**2008**	72009
1983	52587	**1996**	70623	**2009**	73030
1984	52668	**1997**	70557	**2010**	74660
1985	55050	**1998**	70369	**2011**	76190
1986	58614	**1999**	70210	**2012**	77350
1987	62050	**2000**	70213	**2013**	78390
1988	65039	**2001**	69839	**2014**	78390
1989	68280	**2002**	69921	**2015**	78390
1990	68457	**2003**	70819	**2016**	78390
1991	68760	**2004**	71030		
1992	68848	**2005**	71426		

(Source: Food and Agriculture Organization (FAO), 2019)

1.1.4 Employment in Malaysia's Agriculture Sector

In Malaysia, the agriculture sector remains a labour-intensive industry and is facing a shortage of manpower in cultivation activities over time. Figure 1.5 shows the trends of employment in the agriculture sector and the employment growth rate in comparison with the trend of agriculture GDP growth in Malaysia. The employment in Malaysia's agriculture sector as the agricultural labour force has declined from 1.78 million persons in 1980 to 1.61 million persons in 2016 (Table 1.5). According to the Department of Statistic Malaysia (DOSM), agriculture sector contributed 12.1% of total employment in 2016 (DOSM, 2019).

The agriculture employment recorded substantial declines in the years of 1981/1982 (-9.66%), 1996/1997 (-8.92), 2000/2001 (-17.29%), 2010/2011 (-15.05%) and 2015/2016 (-8.21), corresponding with the decline in agriculture growth. Eventually, in 2016, the agriculture growth rate became negative. Therefore, the government should make sure that there is no labour shortage in this industry in order to increase agriculture production.

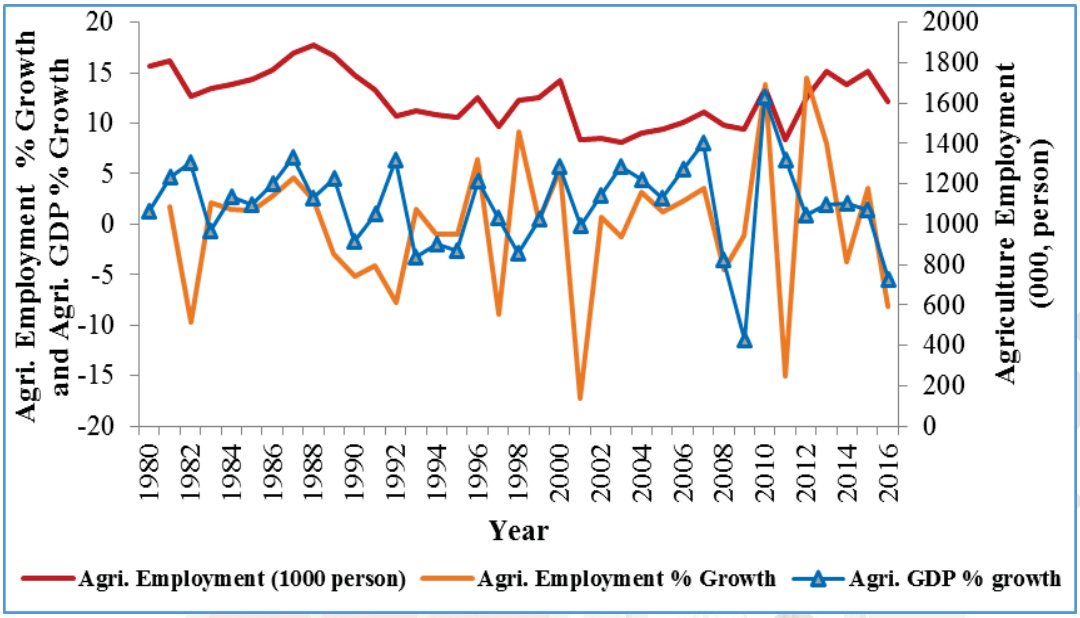

Figure 1.5 : Malaysia's Agriculture Employment and Agriculture GDP % Growth, 1980 – 2016
(Source: Department of Statistics Malaysia (DOSM), 2018/2019)

Table 1.5 : Agriculture Employment (1000 person) and Agriculture Employment Growth rate (%) in Malaysia, 1980 – 2016

Year	Agriculture Employment (1000 person)	Employment Growth rate (%)	Year	Agriculture Employment (1000 person)	Employment Growth rate (%)
1980	1781		**1999**	1624	0.433
1981	1811	1.684	**2000**	1712	5.419
1982	1636	-9.663	**2001**	1416	-17.290
1983	1671	2.139	**2002**	1425	0.636
1984	1695	1.436	**2003**	1408	-1.193
1985	1717	1.298	**2004**	1453	3.196
1986	1765	2.796	**2005**	1470	1.170
1987	1846	4.589	**2006**	1504	2.313
1988	1889	2.329	**2007**	1558	3.590
1989	1833	-2.965	**2008**	1488	-4.493
1990	1738	-5.183	**2009**	1471	-1.142
1991	1666	-4.143	**2010**	1674	13.800
1992	1536	-7.803	**2011**	1422	-15.054
1993	1559	1.497	**2012**	1628	14.487
1994	1543	-1.026	**2013**	1759	8.047
1995	1527	-1.037	**2014**	1694	-3.695
1996	1626	6.483	**2015**	1754	3.542
1997	1481	-8.918	**2016**	1610	-8.210
1998	1617	9.183			

(Source: Department of Statistics Malaysia (DOSM), 2018)

1.1.5 Climate Change Variables in Malaysia

Greenhouse gases (GHGs), such as carbon dioxide (CO_2) are found to influence the world's climate because they will increase the earth's temperature. According to Ruchita and Rohit (2017), increasing CO_2 can cause climate change and consequently decreas**ES** crops yield. Table 1.6 shows that the total CO_2 emission in kilotons (kt) in Malaysia has increased from 1980 to 2016. The CO_2 emission in Malaysia grew rapidly after 1990 due to the transformation of the economy from agriculture to industrial based. In 1997/1998, the CO_2 decreased for about 8.52% and further declined to 107,934.478 kt in 1999. This is because of the financial crisis that happened in Asia in 1997 which has caused the economic downturn and reduced the national industrial production. After 1999, Malaysia's economy recovered and increased its national productivity, hence, the elevated CO_2 release and the increasing trend.

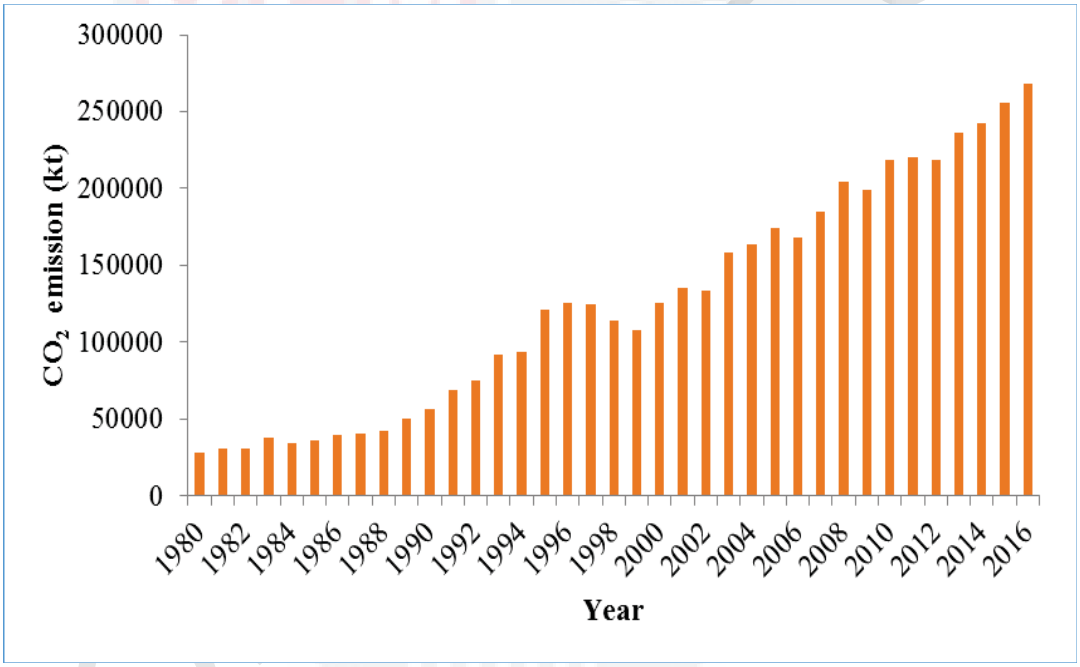

Figure 1.6 : Malaysia's Carbon Dioxide (CO_2) Emission (kt), 1980 – 2016
(Source: World Bank's World Development Indicators (WDI), 2019)

Table 1.6 : Carbon Dioxide (CO2) Emission (kilo ton) in Malaysia, 1980 – 2016

Year	CO_2 Emission (kt)	Year	CO_2 Emission (kt)	Year	CO_2 Emission (kt)
1980	27997.545	**1993**	91722.671	**2006**	167702.911
1981	30824.802	**1994**	94010.879	**2007**	184816.800
1982	30571.779	**1995**	121132.011	**2008**	204031.880
1983	37971.785	**1996**	125374.730	**2009**	198876.078
1984	34697.154	**1997**	124821.013	**2010**	218476.193
1985	36237.294	**1998**	114186.713	**2011**	220405.035
1986	39984.968	**1999**	107934.478	**2012**	218707.214
1987	40762.372	**2000**	125734.096	**2013**	236510.499
1988	42724.217	**2001**	135620.328	**2014**	242821.406
1989	49882.201	**2002**	133742.824	**2015**	256070.790
1990	56592.811	**2003**	158256.719	**2016**	267911.684
1991	68591.235	**2004**	163826.892		
1992	75298.178	**2005**	174486.861		

(Source: World Bank's World Development Indicators (WDI), 2019)

Greenhouse gases (GHGs), especially CO_2 emission causes global warming which leads to climate change that has not only raised the temperature but also affecting the rainfall (Herath et al., 2019). The annual average temperature in Malaysia has an upward trend with acute fluctuation in certain years during 1980 - 2016 (Table 1.7). In Malaysia, the earth surface temperature has increased from 25.26ºC in 1980 to 26.37˚C in 2016 with the temperature in 2016 particularly warmer by about 1.11˚C than in 1980. The average temperature during this period of time was 25.66˚C with a minimum temperature of 25.06˚C in 1984 and a maximum temperature of 26.37˚C in 2016. These changes cause climate disasters such as El – Nino, storm, drought and floods (World Bank, 2018).

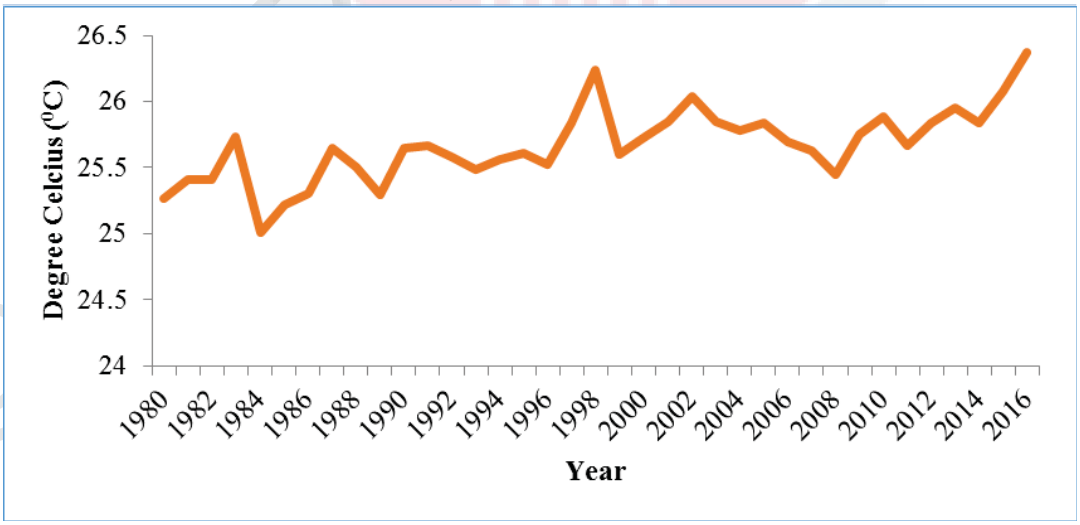

Figure 1.7 : Malaysia's Average Temperature (ºC) per annum, 1980 – 2016
(Source: World Bank's Climate Change Knowledge Portal, 2018)

Table 1.7 : Annual Average Temperature Changes (oC) in Malaysia, 1980 – 2016

Year	Average Temperature (°C)	Year	Average Temperature (°C)	Year	Average Temperature (°C)
1980	25.266	**1993**	25.484	**2005**	25.838
1981	25.408	**1994**	25.563	**2006**	25.698
1982	25.411	**1995**	25.605	**2007**	25.632
1983	25.730	**1996**	25.520	**2008**	25.449
1984	25.013	**1997**	25.842	**2009**	25.751
1985	25.221	**1998**	26.237	**2010**	25.882
1986	25.303	**1999**	25.598	**2011**	25.669
1987	25.645	**2000**	25.721	**2012**	25.842
1988	25.503	**2001**	25.846	**2013**	25.953
1989	25.296	**2002**	26.040	**2014**	25.837
1990	25.649	**2003**	25.844	**2015**	26.073
1991	25.663	**2004**	25.778	**2016**	26.375
1992	25.577				

(Source: World Bank's Climate Knowledge Portal, 2018)

In contrast to the CO_2 emission and temperature, there has been no increasing trend in rainfall, but there have been many obvious fluctuation points (Table 1.8). The average rainfall in Malaysia from 1980 to 2016 was about 254.91 mm. The maximum average rainfall was 311.04 mm in 2008 and the minimum average rainfall recorded was 208.19 mm in 1990 during the period of 1980 to 2016.

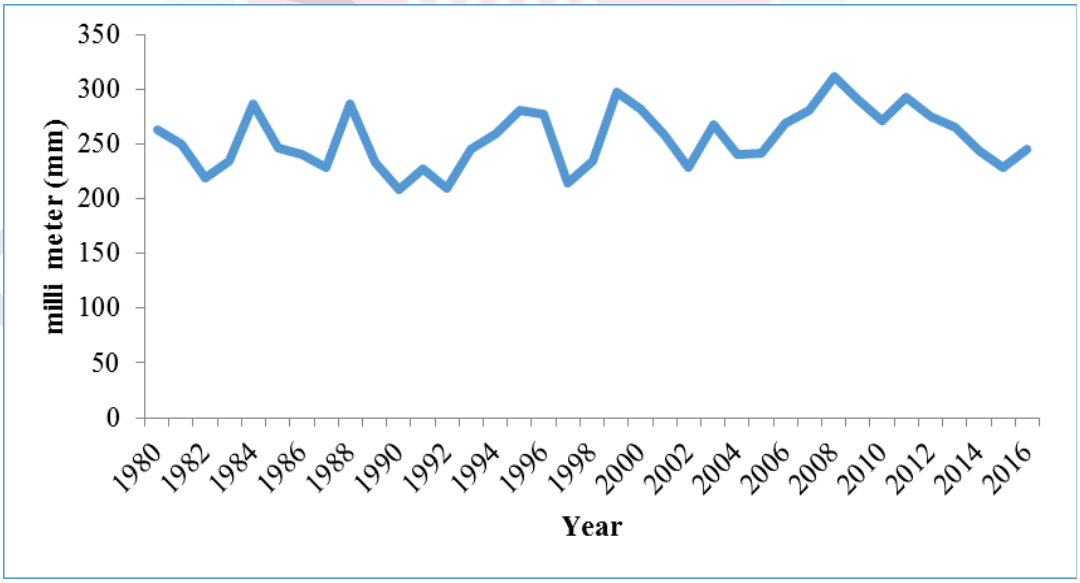

Figure 1.8 : Malaysia's Annual Average Rainfall (mm), 1980 – 2016
(Source: World Bank's Climate Change Knowledge Portal, 2018)

Table 1.8 : Annual Average Rainfall (millimeter) in Malaysia, 1980 – 2016

Year	Average Rainfall (mm)	Year	Average Rainfall (mm)	Year	Average Rainfall (mm)
1980	263.191	**1993**	245.162	**2006**	268.511
1981	249.906	**1994**	258.942	**2007**	280.878
1982	218.656	**1995**	280.793	**2008**	311.042
1983	234.200	**1996**	277.137	**2009**	290.702
1984	286.424	**1997**	214.470	**2010**	270.794
1985	245.763	**1998**	234.986	**2011**	292.972
1986	240.794	**1999**	296.861	**2012**	275.358
1987	228.925	**2000**	281.869	**2013**	265.756
1988	286.490	**2001**	258.156	**2014**	243.540
1989	233.270	**2002**	228.360	**2015**	229.016
1990	208.189	**2003**	267.218	**2016**	244.870
1991	227.710	**2004**	240.573		
1992	209.180	**2005**	241.173		

(Source: World Bank's Climate Knowledge Portal, 2018)

1.2 Climate Change and Agricultural Production in Malaysia

The issue of climate change is now a global challenge and has attracted the attention of world leaders for proactive and expedited planning for low carbon industrial growth, clean and renewable energy sources, agricultural sustainability and low-level energy-intensive economic growth. The relationship between climate change and agriculture is an important issue, since the world's food production resources are under pressure from a rapidly growing population (Matthews and Wassmann, 2003). The agriculture sector vulnerability to the climate is well-founded. It is a general agreement that the temperature and rainfall changes will affect plant growth and crops production (Al-Bakri et al., 2011). Increased temperatures can lead to greater evapotranspiration, leading to a decline in the supply of water. During the dry months, this issue would be further aggravated. Therefore, drought-prone areas can become marginal or inappropriate for the cultivation of some crops, such as rubber, palm oil, cocoa and rice (Haliza, 2009; Zakaria et al., 2007).

Climate change may affect agriculture differently in various parts of the world. It relies on the current condition of the climate and soil, the direction of change, and the resources availability and infrastructure to face with change. It is predicted to reduce crop production in the lower latitudes, however, an increase in production in the high and mid-latitudes. It depends on the present growing conditions. Crops are growing closer to their temperature tolerance limits in low-latitude regions, so any warming exposes them to higher stress. However, increased warming would benefit crops that are currently limited by cold temperatures and short growing seasons in many mid- and high-latitude regions (Kropff et al., 1997). Climate change in Northern Europe, for instance, will create more favourable conditions for crop production and thus, increase the productivity of European agricultural systems (Olesen and Bindi, 2002). Nevertheless, in most developing countries,

including Malaysia, that are located in regions at lower latitudes are more vulnerable to climate change. According to the Malaysia Initial National Communication (INC) submitted to the United Nations Framework Convention on Climate Change (UNFCC), climate change plays a major role in determining crop performance and the key economic crops such as rice, oil palm, cocoa and rubber are more vulnerable to the climate change in addition to the vegetable production, floriculture, aquaculture and animal husbandry in Malaysia (MOSTE, 2000). Additionally, Bin Zainal (2013) asserted that Peninsular Malaysia is the worst affected by climate change as evidenced by decreased in Fresh Fruit Batch (FFB) by about 7.5%.

Malaysia is one of the high greenhouse gasses emitters in which the rate of changes in CO_2 emission is very fast (Al-Amin et al., 2011). Temperature is projected to rise by 0.3–4.5°C as a result of elevated greenhouse gas emissions (Alam, 2010; Alam, Siwar, Molla, et al., 2012). In the course of a hundred years, the heat will cause increase in the sea level by around 95 cm and changes in precipitation may vary by between −30 and +30%. This change may cause drought in many areas which makes it impossible for the cultivation of some crops such as rice, oil palm, rubber and cocoa (Alam et al., 2012). Rice or paddy production in Malaysia is important as a national staple diet (Herath et al., 2019; Masud et al., 2014). It is a high water demand plant; thus, unpredictable climatic changes, such as extreme weather (floods and droughts), are expected to have an impact on the amount of water required. Previous studies have shown that increased air temperature has an inverse impact on rice yield and its grain quality (Baker et al., 1992; Saseendran et al., 2000). High temperature cause increased the atmosphere transpiration rate, reduced photosynthesis, and shortens the growth duration of the rice plant. The Malaysian Agricultural Research Institute (MARDI) has estimated that an increase in daily temperature by 1°C will reduce rice production by 10% in Peninsular Malaysia (Abdullah 2007). Additionally, flood is another catastrophe related to climate change in Malaysia due to extreme rainfall. The rainfall fluctuations of ±14 % and carbon dioxide concentration of 400–800/ppm could have negative effects on paddy farms. Vaghefi et al. (2016) projected that an increase in temperature will reduce the rice yield by 12% and the changes in rainfall pattern will reduce the rice yield by 31.3% until 2030. Therefore, it is evident that climate changes primarily affect rice production which is linked with other climate and environmental factors (Baharuddin, 2007).

Similarly, some other key economic crops such as oil palm and rubber are affected by climate change in Malaysia (Alam et al., 2010; MOSTE, 2000). There are about 39.2% of total land use or about 5.18 million hectares of land planted with tree crops like rubber, oil palm, cocoa, coconut, fruits and vegetables (Haliza, 2018). Reports suggest that 6% of land under oil palm and 4% planted with rubber may be flooded or abandoned as a result of rising sea level. Moreover, in areas that are prone to drought, such agriculture land would become unsuitable for cultivating crops like oil palm and rubber. In recent years, palm oil production has fallen due to direct and indirect climate change effects (Bin Zainal, 2013).

1.3 Malaysia's Climate Change Policy

Climate change is emerging as the most significant environmental challenge facing modern society. It has evolved into a global environmental issue that dominates the international agenda and one of humanity's most challenging problems. Climate change is not a distant possibility anymore and it is a scientifically proven reality now that is already affecting all of us. In recent decades, climate change and its effects on people's economic and livelihood have become the key issues for scientists and policymakers all around the world (Solaymani, 2018). It is anticipated that all climate-sensitive sectors of the economy, such as agriculture, water, infrastructure, coast and health, would suffer from adverse impacts at both national and global levels. Therefore, this will have substantial international and intergenerational implications in the context of wider societal goals for sustainable development.

Economic analysis plays a vital role in contemporaneous national policymaking, as most important decisions fall within the economic sphere. Principally, the development level of a country is measured by GDP or monetary economic growth. Therefore, an economic model that is less materialistic and energy-efficient must be introduced in order to achieve sustainable development, particularly in the long term. The development of a sustainable economic model should recognize the environmental impact as part of the development agenda and establish a viable relationship between the two components. In order to achieve a sustainable economic model, it is essential that innovative policy instruments are capable of creating the necessary shifts in economic trends or patterns. Thus, the climate change policy plays a role in leading a country towards a sustainable economic development model by controlling emissions of GHGs with appropriate sectoral policies in place.

Malaysia has always advocated sustainable development, taking into consideration of economic growth, social well-being and conservation of the environment in its development planning. Most importantly, sustainable development has been the cornerstone of the success of this country. Despite this, there is much to be done to meet the nation's full potential. Studies conducted under the auspices of the Malaysian Ministry of Natural Resources and Environment have provided an insight into possible climate change scenarios and potential threats to the sustainability of this country. In addressing the climate change challenges, everyone has a role to play but in order to be successful, we must all act in unison. Therefore, the National Policy on Climate Change provides a framework for mobilizing and guiding government agencies, industry, the community, as well as other stakeholders and major groups to address climate change challenges in a holistic manner.

In general, Malaysia adopts the "precautionary principle" policy action in order to mitigate or adapt to climate change, even though there are still scientific uncertainties. A National Climate Committee was formed in January 1995 which

was chaired by the Secretary-General of the then Ministry of Science, Technology and Environment, but it is now coordinated, all climate change-related activities, by the Ministry of Natural Resources and Environment. The relevant government agencies, stakeholders from the business and civil society groups are the members of the committee. The strategies adopted by the Committee include the reduction of heavy reliance on fossil fuels in the energy sector, the promotion of renewable energy and energy conservation, public awareness campaign, sustainable forest management, food protection and the undertaking of a Coastal Vulnerability Index (CVI) report, which serves as a basis for the creation of adaptive measures to mitigate the impact of rising sea levels. Existing environment-related policies and relevant national policies that have an impact, directly or indirectly, on climate include change include the Third National Agricultural Policy (1998-2010), National Automotive Policy (2009), National Physical Plan (2006), National Policy on the Environment (2002), National Policy on Biological Diversity (1998), National Energy Policy (1979), and National Forestry Policy (1978).

Environment-related policies having an impact on climate change include the National Forestry Policy (1978), National Energy Policy (1979), National Policy on Biological Diversity (1998), National Policy on the Environment (2002) and Third National Agricultural Policy (1998-2010).

In 2010, the Malaysian government launched the National Policy on Climate Change in order to mainstream and provide a framework for the country's various activities in this area (Figure 1.9). The policy study on climate change was carried out by CEMD in collaboration with LESTARI (Institute for Environment and Development) under the Ministry of Natural Resource Environment (MNRE). Malaysia's National Policy on Climate Change consists of several key elements, including objectives, principles, strategic thrusts and key actions, and is designed to ensure a climate-resilient and low-carbon economy that fulfils national sustainability aspirations. The objectives, principles and strategic thrust of the draft policy for integrating responses into national policies and programmes in order to strengthen the resilience of development to the future impacts of climate change on sustainable development, are presented in Appendix-A. The key objectives of the National Policy on Climate Change in Malaysia include:

- Mainstreaming measures to address climate change challenges through wise management of resources and enhanced environmental conservation resulting in strengthened economic competitiveness and enhanced quality of life for sustainable development;
- Strengthening institutional and implementation capacity to enhance opportunities in reducing the negative impact of climate change, and
- Integrating the responses into national development plans, policy plans and programmes to strengthen the resilience of development from potential climate change future impacts.

The strategic principles and directions of the draft national policy on climate change issues in Malaysia include (Tiong et al., 2009):

- Development of a Sustainable Path: integrates national development plans in order to fulfil the country's aspiration for sustainable development;
- Sustainability of Environment and Natural Resources: Indicates climate change issues that contribute to environmental conservation and sustainable use of natural resources;
- Integrated Planning and Implementation: Integrates planning and implementation of climate-proof development;
- Effective Participation: indicates the improved participation of stakeholders for the effective implementation of climate change responses; and
- Common but Differentiated Responsibility: incorporates international involvement in climate change issues (Al-Amin et al., 2012).

Among the key initiatives, the low carbon economy is one of the key initiatives taken by the Malaysian government to combat global warming (Al-Amin et al., 2013; Haliza, 2018).

In 2010, the Ministry of Natural Resources and the Environment announced a reduction in carbon emissions from 187 million tons to 74.8 million tons between 2005 and 2020 – equivalent to a 40% reduction in carbon emissions. This is part of alternative energy sources to address the challenges of the 2100 climate change transformation (Al-Amin, Filho, et al., 2011). A program called the Small Renewable Energy Program (SREP) was established by the national government. Some of the policies do not directly address the issue of climate change. However, they make an indirect contribution to addressing the impacts of climate change (Pereira and Tiong, 2008).

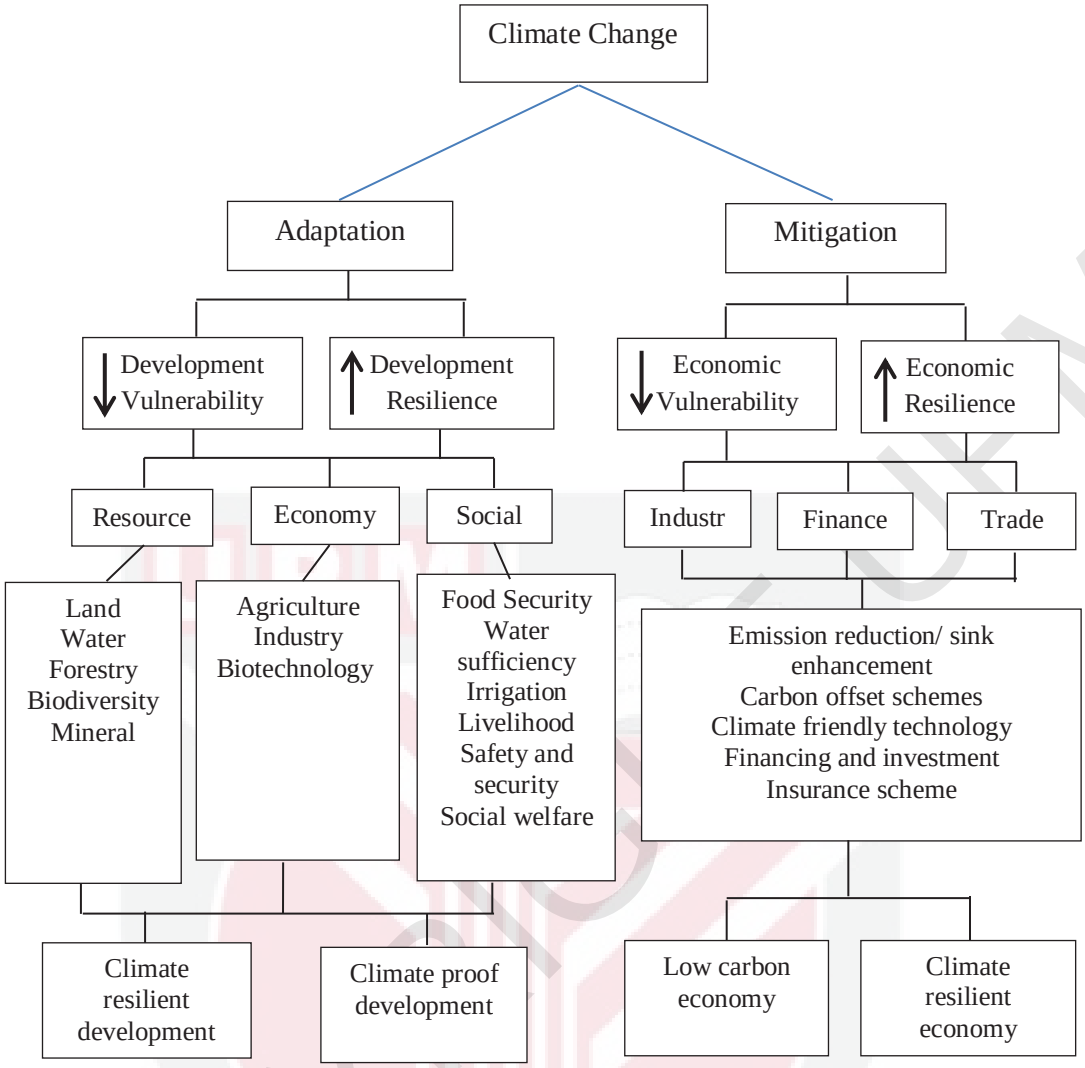

Figure 1.9 : Framework of the Malaysia's National Policy on Climate Change (Source: Al-Amin et al. 2013)

1.4 Problem Statement

In Malaysia, agriculture is an important sector that contributes about 8.6% to national Gross Domestic Product (GDP) and 12.1% to total employment in 2016. Even though the percentage of agriculture contribution to national income has decreased from about 23.03% in 1980 to 8.65% in 2016 and the percentage share in total employment has declined from around 37.2 to 11.37% in 1980 and 2016, respectively, the agriculture sector remains a backbone to Malaysia's economic growth and is critical to the food production and food security in Malaysia.

In general, crop production is affected biophysically by climatic change variables such as temperature and rainfall. GHGs are the main cause of climate change and it has been estimated that more than 60% of climate change is caused by carbon dioxide (N'zué, 2018; Sinha and Bhatt, 2017). The increase in atmospheric CO2

negatively affects agriculture through rising temperature and changes in rainfall pattern that consequently led to climate disasters (Mulatu, Eshete and Gatiso, 2018). Additionally, the increase in atmospheric temperature interferes with the crop nutrition system and causes crops to become more vulnerable to pests and diseases that decrease their yield. Malaysia's GHGs of CO_2 emission is in the increasing trend, meaning that climate change could be happening in Malaysia. The increasing temperature and CO_2 warn that Malaysia is also facing the risk of agriculture production shortage as well as food production in the future (World Bank, 2019).

From the economic point of view, for instance, agriculture is one of the labour-intensive sectors and it is facing a serious declining employment problem due to the shifting in the labour force to other economic sectors. Additionally, the agriculture employment in Malaysia recorded substantial declines in the years of 1982, 1997, 2001, 2011 and 2016, corresponding with the decline in agriculture gross domestic product growth. In a nutshell, Malaysia's agriculture production is showing a lower growth rate which is mainly due to two main factors, i.e., economic factors and climatic factors. The labour shortage and the cost of investment are the related factors that can affect Malaysia's agriculture production in the short and long term. Additionally, the agriculture sector, especially crop production, is highly related to temperature and rainfall. Hence, climate change is one of the important factors to cause an opposite effect on Malaysia's agriculture production.

1.5 Research Objectives

In this study, the general objective was to examine the impact of climate change and macroeconomic factors on Malaysia's agricultural production. To be more specific, this study also aimed to:

i. investigate the impact of climate change on Malaysia's agriculture production, and
ii. determine the specification of macroeconomic factors as control variables on Malaysia's agriculture production.

1.6 Research Questions

i. What factors affect Malaysia's agriculture production?
ii. Does climate change in Malaysia pose significant implication to agriculture production?
iii. How to increase Malaysia's agriculture production?

1.7 Significance of the Study

Agriculture is considered a strategic sector that largely contributes to Malaysia's economy and is critical to food production. It is as an upstream industry to support the food supply that highly determines Malaysian food security. In addition, agriculture is a predominantly labour-intensive sector in Malaysia. However, climate change poses one of the main threats to agriculture production. Climate change in Malaysia will affect several significant sectors, mainly agriculture, forest, energy and public health. It directly affects agriculture as the pattern of precipitation and temperature change. Thus, any changes in agricultural resources will create profound risks in the life of people in this sector that will consequently endanger food security.

Studies have been carried out to examine the impact of climate change and agriculture production, but there is a lack of empirical study on the link between climate change and aggregate agriculture production at the macro level. The previous researchers have examined the impact of climate change on specific crops. This particular study explains the relationship between agriculture production and climate change, i.e., temperature and rainfall in addition to the macroeconomic factors as the control variable in the production function. The significance of this research is to demonstrate the importance of agriculture to ensure the growth of the economy and enhance food security in Malaysia.

Specifically, the informative findings of this study will assist the government, policymakers and implementers to make policies in supporting food and agricultural producers that can increase the export, GDP, employment and production that have a direct effect on the government's income and total GDP. On top of this, information obtained could benefit the farmers to understand the impact of climate change on their crop productivity and production and mitigate the impact of climate change for better yield and quality products.

In the context of academic research, the output of this study will enrich our understanding of the contribution of economic factors in aggregating agriculture production at the macro level. This is because each factor has a significant impact on the production and adaptive capacity to vulnerability of crop producers in Peninsular Malaysia.

1.8 Organization of the Thesis

This study is organized into five chapters. Chapter 1 introduces the agriculture sector, related economic factors and the climate change situation in Malaysia. Chapter 2 reviews and discusses theoretically and empirically relevant related past studies on the impact of climate variable and economic factors on agriculture production. Chapter 3 presents the method and technique adopted and statistical analysis employed in the study. Chapter 4 presents and interprets the result of the study and discusses the results with the past studies. Finally, Chapter 5 summarizes and highlights the major findings of the study, policy implications, limitations and contribution of this research and suggestions for future researches in this area.

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