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IMPACT OF TEMPERATURE, RAINFALL AND FLOODS ON OIL PALM PRODUCTION IN MALAYSIA- A REVIEW

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ABSTRACT: Floods, rainfall, and temperature are all becoming major ecological threats. The findings of this study indicate that the production of oil palm has been negatively impacted by temperature, rainfall, and floods and will continue to do so. As can be shown, the El Niño and flood events in 1997–1998 and 2015–2016 significantly decreased oil palm yield turnover by altering the overall weather pattern and influencing the soil and plant physiology. A 1–4°C increase in temperature was anticipated to result in a 10–41% decrease in oil palm yield in Malaysia, demonstrating the significant effects of rising average surface temperatures on oil palm productivity. Elevated temperatures worsen the rate of evapotranspiration, which dries up the soil and increases water stress, which ultimately leads to slower growth and a poor yield. In addition to making days warmer and nights colder, rising temperatures alter the ecology of a number of diseases and pests. Because of their increased population and increased ability to adapt to their changing environment, these pests and diseases have the potential to spread across the plantations and cause an epidemic or possibly a pandemic. The pollination process may be hampered by pollinating insects being attacked by other organisms, which could result in a decline in their population. In addition to a broader regional distribution and anticipated drier conditions during the southwest monsoon towards the end of the twenty-first century, the rainfall projection showed heavy rain around the years 2081–2100. In order to address the effects of temperature, rainfall, and flooding on oil palm production, the study makes the following policy recommendations: improved variety, improved institutional research, cooperation between producer and major consumer countries in research, technology transfer, environmental education, management skills, and extension services to oil palm growers; sustainable land use policy and expansion without deforestation; and easier access, communication, and availability of academic findings.

Key words: Temperature, rainfall, floods, oil palm, oil palm adaptation and Malaysia.

INTRODUCTION

While climate refers to a region's average weather over a period of more than 35 years, weather indicates the state of the atmosphere at the moment. According to the **IPCC (2007)**, climate change is defined as a shift in the climate's state that is detected (for example, by statistical tests) by variations in the mean and/or variability of its attributes and that lasts for several decades or more. Climate change has a significant impact on agricultural and food production, making it a global economic concern, particularly for industries that heavily depend on the climate (such as agriculture) (**Zimmermann *et al.*, 2018**).

An essential item that makes a significant contribution to Malaysia's economy is oil palm (*Elaeis guineensis*). A highly productive oil plant, oil palm is used to make biodiesel, cosmetics, medications, cooking, and grocery items (**Paterson *et al.*, 2018**). About 85% of the

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world's palm oil is currently produced in Malaysia and Indonesia. Because of its low production costs, easy planting process, high efficiency, and enormous output potential, oil palm is very profitable (**Paterson, 2020a,b**). About 38% of Malaysia's GDP in 2019 came from oil palm output, which dominated the country's agricultural sector (**Department of Statistics, 2021**). According to **Abdul Rahman *et al.* (2018)**, the nation is the world's largest exporter of palm oil and related goods and the second-largest producer of oil palm, behind Indonesia. Accordingly, Malaysia produces 39% of the world's palm oil and exports 44% of it (**Malaysian Palm Oil Council, 2019**). However, India, China, the United States (USA), the European Union (EU), Pakistan, Bangladesh, Nigeria, the Philippines, and other nations are the world's biggest importers and consumers of palm oil (**Kushairi *et al.*, 2018; Maluin *et al.*, 2020**).

Due to the quick growth and conversion of tropical rainforests into oil palm plantations, oil palm is now produced at a low cost from planting to harvesting, making it a lucrative crop with a fast turnover rate. Every year, the palm oil industry draws investments totaling more than USD 50 billion (**Paterson and Lima, 2018**). The creation of chemicals, detergents, and biodiesels are only a few of the uses for crude palm oil (CPO) (**Zahan and Kano, 2018**). However, there hasn't been any agreement among scientists regarding the effects of oil palm growth (**Tang and Al Qahtani, 2020**). In addition to boosting GDP and local livelihood, some claim that oil palm expansion mitigates the effects of climate change by producing ethanol as an alternative energy source. However, others worry about the destruction of natural forests and environmental degradation, asserting that agriculture is the only human activity that devastates the earth's natural system.

The fluctuating patterns of rainfall in terms of both length and severity define Malaysia's climate (**Tangang *et al.*, 2018 and Tang, 2019**). Over the past 20 years, there has been an increase in rainfall variability (**Tang, 2019**). There is no doubt that a shift in the climate is shown by the growing number of hot years. Malaysia saw disastrous floods in 1997–1998 and 2006–2007, which claimed many lives and destroyed numerous properties.

Examining the effects of climate change (temperature, precipitation, and floods) on oil palm and determining how Malaysian farmers are adapting to these effects are the goals of this study.

Methodology

A systematic review of the literature was part of the investigation. Reputable databases like Scopus, Elsevier, Pro Quest, Research Gate, and Google Scholar were used to retrieve articles relevant to this study. Using pertinent search phrases, such as "climate change," "oil palm," "climate change (temperature, rainfall, and floods) and oil palm," "oil palm and extreme events," and "oil palm adaptation," the materials were gathered from search engines. The collected documents' abstracts were thoroughly examined in order to classify them into a variety of relationships and themes. Only the pertinent original papers remained for additional evaluation after duplicates were eliminated at this point. Articles published prior to 2000 that were not in English were not included. Articles about adapting to and reducing the direct and indirect effects of climate change were chosen for this study based on their titles or abstracts. Additionally, full-text reviews and evaluations of papers describing adaptability and adaptable capacity were incorporated. Furthermore, publications that discussed the difficulties brought on by climate change, the perceived effects of extreme events on oil palm, the unpredictability of temperature and rainfall, climate change resilience, susceptibility, and future climate projections were included.

Oil Palm Production

Both large-scale and smallholder plantations are used in Malaysia to produce oil palm (**Ahmed *et al.*, 2021**). A plantation is considered large if it covers between 3000 and 20,000 hectares. Malaysia has constructed 423 operational palm oil processing facilities. According to **Herdiansyah *et al.* (2020)**, the establishment of large processing firms and the expansion of oil palm plantations maximize profit at cheap cost and minimum labor. These businesses are more focused on oil palm variety seeds that mature early and yield a lot. Smallholders may not be able to distinguish local seeds from the enhanced variety, and they lack the necessary funds to obtain high-yielding variety seeds (**Zen *et al.*, 2006**).

Oil palm–planted area

Oil palm is grown over 18.1 million hectares in 43 countries in the lowlands of the tropics (**Dislich *et al.*, 2017**). With 7.1 million hectares, Indonesia is the leading producer of oil palm, followed by Malaysia with 5.9 million hectares (**MPOB, 2020**). Remarkably, 85% of global CPO output comes from these two nations. The oil palm planted area increased significantly in the 1960s and 1970s as a result of Malaysia's agricultural transformation policy, which saw more land changed from rubber to oil palm (**Nambiappan *et al.*, 2018 and Shevade and Loboda, 2019**). Due to a lack of adequate land in Peninsular Malaysia, Sabah and Sarawak have seen the majority of expansion in recent years (**Nambiappan *et al.*, 2018 and Shevade and Loboda, 2019**). According to **Nambiappan *et al.* (2018),** Peninsular Malaysia accounted for roughly 47% of the planted area in 2016, followed by Sabah (27%), and Sarawak (26%). In general, Malaysia is seeing a rise in the area planted to oil palm (**MPOB, 2020**) (Figs. 1-3).

Palm oil exports

The two main products that are derived from oil palm for export are palm oil and kernel (**MPOB, 2011**). Malaysian exports provide around half of the global demand for palm oil products (**Sumathi *et al.*, 2008**). Exports of oil palm products, such as palm oil, palm kernel oil, palm kernel cake, oleo-chemicals, biodiesel, and completed goods, increased by 2.8% in 2009. Over 17 million metric tons of palm oil are exported from Malaysia each year (**MPOC, 2021**). According to data from 2020, Malaysia exported 4.42 million metric tonnes of CPO and 12.95 million metric tonnes of processed palm oil (PPO) (**MPOC, 2021**). CPO exports are expected to increase to around 5.5 million metric tonnes in 2021, a 24.4% year-over-year increase from 2020. This is because Malaysian CPO is now more competitively priced due to the Indonesian government's revision of its export duty policy (**MPOC, 2021**). Additionally, it is anticipated that Malaysia's CPO production will moderately expand from 19.14 million metric tonnes in 2020 to 19.6 million metric tonnes in 2021 (**MPOC, 2021**). China (2,730.66 metric tonnes), India (2,726.66 metric tonnes), the Netherlands (1,072.95 metric tonnes), Pakistan (1,003.72 metric tonnes), the Philippines (693.03 metric tonnes), Turkey (615.87 metric tonnes), the USA (540.35 metric tonnes), Kenya (520.76 metric tonnes), South Korea (453.76 metric tonnes), and Italy (439.05 metric tonnes) were the top destinations for Malaysia's oil palm exports in 2020 (**Statista, 2021**) (Tables1-4).

Impact of Temperature, Rainfall and Floods on Oil Palm Production

Temperature

The average global temperature increased by 0.3 to 0.6°C during the past century. Indeed, since 1970, the warming trends have persisted, increasing by 0.15°C every ten years (**Tangang *et al.*, 2018**). Between 1980 and 2002, the mean temperature fluctuated from 0.5 to 2.0°C year. The northeast monsoon season in December and January had the lowest recorded temperature (**Information Bulletin, 2017**), whereas Kota Bharu had the highest recorded temperature, with an average of 28°C (**Tangang *et al.*, 2018**). According to data gathered from 23 Malaysian weather stations, there were more hot days and a daily mean average temperature above 28°C (**Tangang *et al.*, 2017 and Tang, 2019**). Beyond the mean annual average of 26–28°C, the majority of meteorological stations showed positive trends in severe temperatures (**Hanim *et al.*, 2015 and MESTECC, 2018**).

According to the Regional Hydroclimate Model for Sabah and Sarawak (RegHCM-SS), Sabah and Sarawak's average annual temperature was expected to climb by 1.5°C and 3.7°C, respectively, between 2040 and 2050 and 2090 and 2100. Specifically, the mean annual temperature for Sarawak was predicted to be 1.23°C in 2040–2050 and 3.10°C in 2090–2100. According to the General Circulation Model, which was used from 1961 to 1999, Malaysia Borneo and Peninsular Malaysia may experience temperature increases of 1.0 to 3.5°C and 1.1 to 3.6°C, respectively, until 2095 (**Malaysian Meteorological Department, 2009**). By 2100, warmer nights are expected to rise by 46–95% and warmer days by 28–75%. Malaysia's peninsula appeared to be less affected by warming, nevertheless (**Abdul Rahman, 2018 and Tang, 2019**). In a similar vein, trends in temperature change point to a general warming in Malaysia.

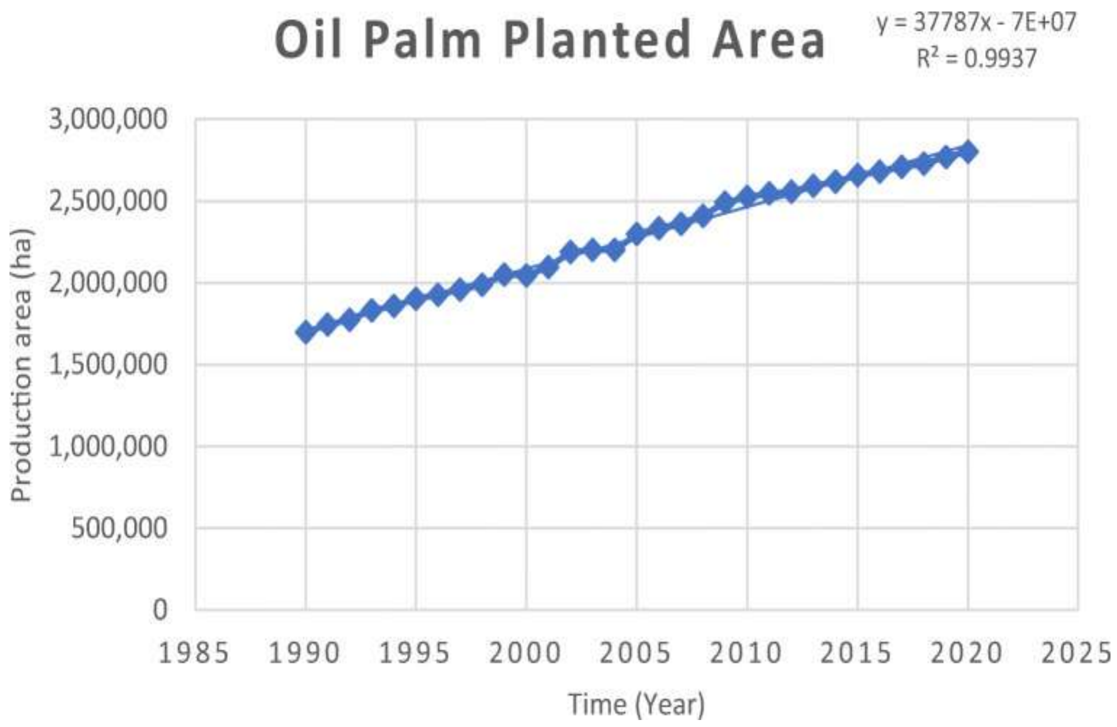

Fig. 1. Trend of oil palm planted area in Malaysia 1990–2020 MPOB (2020)

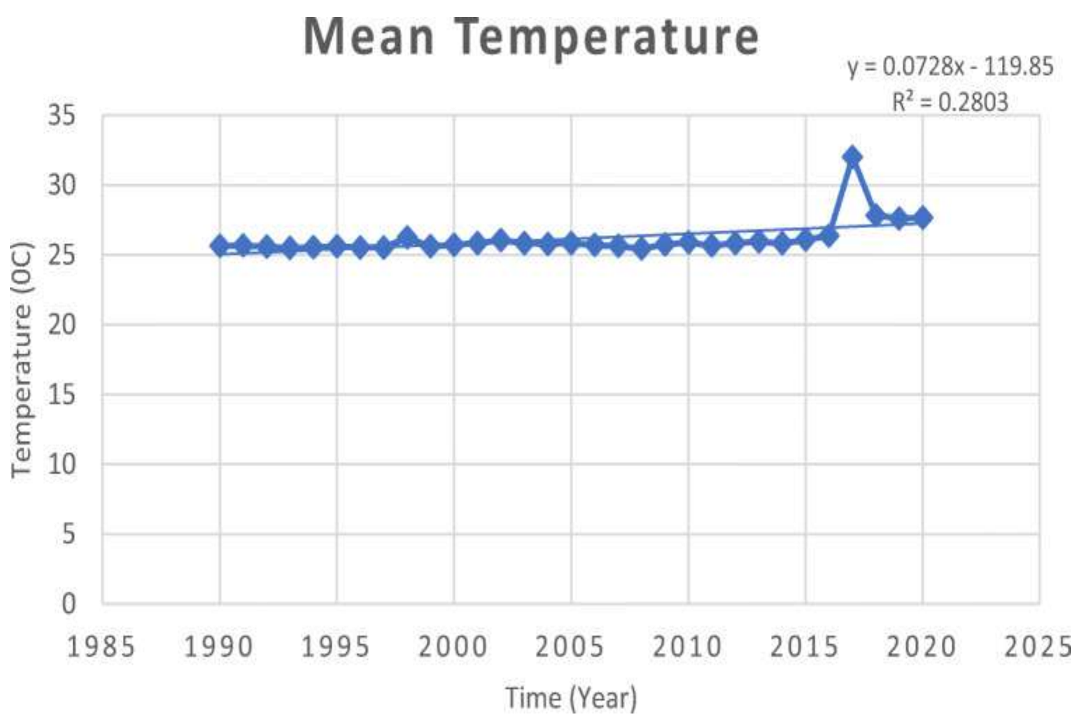

Fig. 2.Trend of mean temperature in Malaysia 1990–2020.

<u>Source</u>: World Bank Climate Knowledge Portal (2021).

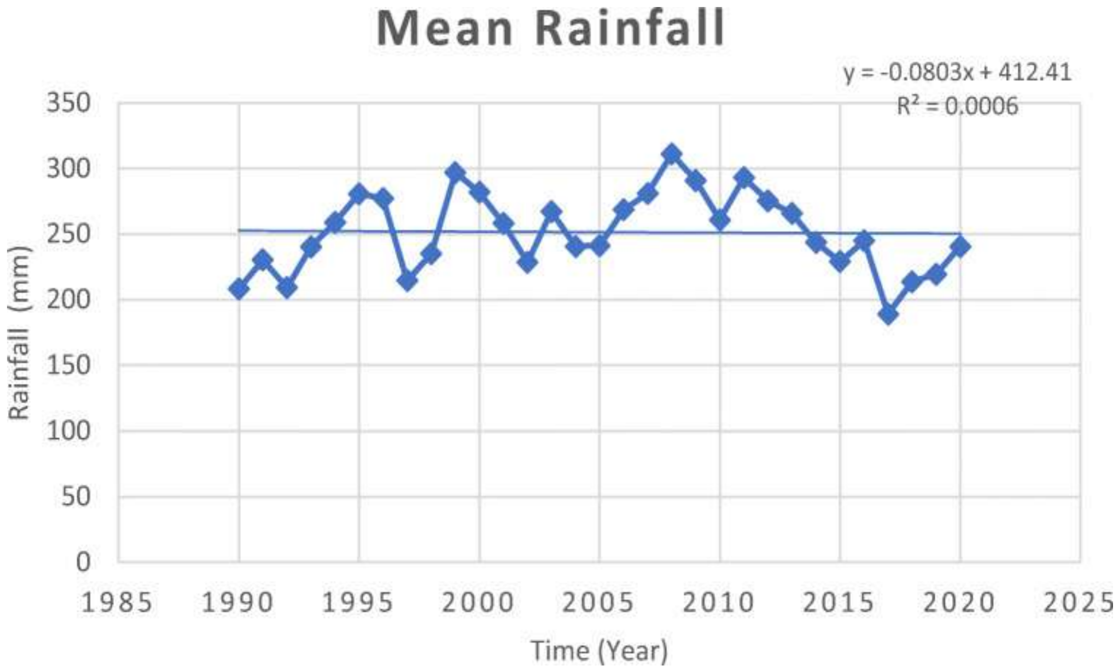

Fig. 3. Trend of mean rainfall in Malaysia 1990–2020

<u>Source</u>: World Bank Climate Knowledge Portal (2021).

Table 1. Crop type and yield in respond to changing temperature in Southeast Asia

Region	Temperature	
Southeast Asia	+2°C C3 crops---------C4 crops −23.71 −-23.71	+ 4°C C3 crops---------------C4 crops −43.60 −43.60

<u>Source</u>: Sarkar *et al.* (2020). Note: cereals, vegetables, and oil seeds are C3 crops; while sugar cane and cereal grains are C4 crops

Table 2.Biotic and abiotic factors that affect oil palm yield

Biotic and abiotic factors	Anticipated changes/outcome for the 21st century	Expected outcome on oil palm yield
Average annual rainfall	Influenced by local geographical differences. Increase in some locations, while decrease in others.	Heavy rainfall without prolong flooding increased yield turnover, while low rainfall depicted low yield harvest (FFB)
Uncertainty and rainfall variability	Low rainfall accompanied with droughts and frequent flooding	Yield decline drastically
Temperature variability	Increase	High evapotranspiration, salinity and dry soil
Carbon dioxide concentration (CO_2)	Increase	High yield
Sea levels	Increase	Damages at coastal plantation and incurred losses
Pests and diseases	Increase	Damages oil palm and affects yield
Pollinators	Decrease	Reduction in yield

<u>Source</u>: Fleiss *et al.* (2017).

Table 3. Exports of all palm products in Malaysia

Product	Unit	Jan–Dec 2020	Jan–Dec 2019	Change (Mt)	Change (%)
CPO	MT	4,423,694	3,827,915	595,779	15.56
	RM Million	12,101.53	8,019.42	4082.11	50.90
PPO	MT	12,945,171	14,643,150	(1,697,979)	(11.60)
	RM Million	36,792.80	33,628.59	3164.21	9.41
Palm oil	MT	17,368,865	18,471,065	(1,102,200)	(5.97)
	RM Million	48,894.33	41,648.01	7246.32	17.40
CPKO	MT	416,836	334,179	82,657	24.73
	RM Million	1390.84	855.59	535.25	62.56
PPKO	MT	802,856	752,075	50,781	6.75
	RM Million	3051.23	2710.61	340.62	12.57
Palm kernel oil	MT	1,219,693	1,086,254	133,439	12.28
	RM Million	4442.06	3566.20	875.86	24.56
Palm kernel cake	MT	2,568,704	2,492,738	75,966	3.05
	RM Million	1362.05	1016.91	345.14	33.94
Oleo chemicals	MT	3,058,031	3,280,127	(222,096)	(6.77)
	RM Million	12,467.56	12,299.69	167.87	1.36
Finished products	MT	561,279	593,714	(32,435)	(5.46)
	RM Million	2610.75	2558.38	52.37	2.05
Biodiesel	MT	378,582	609,777	(231,195)	(37.91)
	RM Million	1354.54	1603.77	(249.23)	(15.54)
Others	MT	1,500,240	1,345,502	154,738	11.50
	RM Million	1634.79	1038.23	596.56	57.46
Total	MT	26,655,394	27,879,177	(1,223,783)	(4.39)
	RM Million	72,766.09	63,731.19	9034.90	

Source: Malaysian Palm Oil Council [MPOC] 2020. Note: Metric tonne (MT), Malaysian ringgit (RM), crude palm oil (CPO), processed palm oil (PPO), crude palm kernel oil (CPKO), processed palm kernel oil (PPKO)

Table 4.The losses in oil palm plantations for each return period

Flood events (years ARI)	Total area (ha) affected	Total FFB (tonnes)	Total price loss (million RM)
10	1759.97	2446.36	1.55
50	3642.32	5062.82	3.21
100	4249.62	5906.97	3.75

Source: Muhadi *et al.* (2017)

Temperatures in Malaysia are predicted to increase by up to 1.5°C by 2050 (**Abdul Rahman, 2018**). According to **Tangang *et al.* (2018)**, Malaysia is expected to have temperature increases of 2.5–3.9°C, 2.7–4.2°C, and 1.7–3.1°C by the end of the twenty-first century.

Many countries' agricultural environments were impacted by the 0.85°C increase in the average world temperature between 1880 and 2012 (**IPCC, 2014 and Allen *et al.*, 2018**). Temperature variability might be detrimental to oil palm and other crop output, according to scientific literature (**Sarkar *et al.*, 2020 and Ahmed *et al.*, 2021**). The way that various crops react to temperature changes has an impact on yield turnover (**Sarkar *et al.*, 2020**).

According to **Paterson and Lima (2018) and the Ministry of Natural Resources and Environment (2010)**, a 2°C increase in temperature might cause a 30% decrease in oil palm yield. A 1–4% increase in temperature could result in a 10–40% decrease in oil palm output (**Sarkar *et al.*, 2020**). According to **Zahal *et al.* (2018)**, the effects of temperature variability caused a modest decline in CPO output in 2009, from 17.00 metric tons to 16.17 metric tonnes. The production of CPO decreased by 2.5% (5.3 MT) per hectare in Sabah and 6.1% (9.5 MT) per hectare in Peninsular Malaysia (**Malaysian Palm Oil Board, 2010**). In 2009, the combined effects of temperature variability resulted in a 6.1% decrease in FFB production and a 0.2% decrease in oil extraction rate. As a result, FFB decreased by 7.5% in Peninsular Malaysia, 4.7% in Sabah, and 2.6% in Sarawak (**MPOB, 2010**). Malaysian oil palm net revenue is significantly impacted nonlinearly by temperature variability. For Peninsular, Sabah, and Sarawak, the losses from the overall marginal rise in temperature were RM 40.55 million, RM 48.69 million, and RM 37.61 million ha−1, respectively. According to **Zahal *et al.* (2018)** and Paterson and Lima (2018), oil palm revenue would decrease by RM 341.29 (RM ha^{-1}) for Peninsular Malaysia, RM 127.43 (RM ha^{-1}) for Sabah, and RM 51.80 (RM ha^{-1}) for Sarawak by the years 2029, 2059, and 2099.

Malaysia is experiencing more heat waves and rising temperatures (**Filho *et al.*, 2018**). Temperature increases hasten the pace at which water evaporates from the soil, making it drier and exacerbating the effects of water scarcity on oil palm. According to projections, oil palm would experience high temperatures in Southeast Asia in 2100. **Sarker *et al.* (2020)** asserted that, as shown in certain coastal regions of Sabah, even a slight increase in temperature could boost harvest production. Temperature increases favor the ecology of diseases and pests and alter their fecundity, or physiological capacity for reproduction. As temperatures rise, weevil species may have less pollination activity. Diseases that could drastically lower the population and hence lower FFB output could threaten other pollinators, such as E. kamerunicus, an African native introduced to Southeast Asia.

Rainfall

Rainfall patterns seemed to fluctuate between 1990 and 2020, especially in Sabah and Peninsular Malaysia. Vibrant variations in rainfall patterns across time were highlighted by historical meteorological data (**Tang, 2019**). The northeast monsoon, which brought with it wet moisture throughout the region and a strong northeasterly wind from the Tropical Western Pacific towards the South China Sea between November and February, was blamed for the increase in rainfall duration and intensity. According to **Ahmed *et al.* (2021)**, there would likely be an increase in the frequency of heavy rains, particularly during the northeast monsoon and the last quarter of each year. According to the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emission Scenarios (SRES A2, A1B, and B2), rainfall in Southeast Asia is expected to rise by around 20 to 40 percent throughout the summer. Based on the Representative Concentration Pathway (RCP 6.0) scenario, **Syafrina *et al.* (2017)** predicted a rise in the hourly length and intensity of rainfall for the years 2081–2100 with spatiotemporal variation in the distribution within Peninsular Malaysia.

In oil palm plantations, a lack of moisture can lead to nutrient deficiencies in the trees and impact flower development, increasing abortion, decreasing productivity, and producing long inflorescences that last for about 8 to 9 months. OER will decline approximately 11 months after two or more consecutive months of low rainfall. A drop in FFB yields and a delay in harvest could result from excessive rains. Additionally, pollination, which takes place six months prior to fruit maturation, is diminished by heavy rain (**Henson *et al.*, 2008**). Oil palm FFB yield is significantly impacted by monthly rainfall, primarily through pollination, sex determination, inflorescence, and abortion (**Oettli *et al.*, 2018**). After a 5-month lag, a month with high rainfall is followed by a lower FFB output. Likewise, after a 5-month lag, a large FFB yield follows a month with little rainfall. This means that rainfall has an impact on the quality of FFB output, mainly through pollination or fruit sets. According to **Ahmed *et al.* (2021)**, excessive rainfall may result in less hours of sunshine on the plantation, which may disrupt photosynthesis and the synthesis of carbohydrates needed for the creation of dry matter and tissue maintenance respiration. Similarly, a 32% variation in rainfall results in a $1,118 annual drop in palm oil earnings (**Paterson and Lima, 2018**).

Flood

Heavy rainfall and unusual variations in air temperature have led to an increase in the frequency and severity of flood disasters. Floods can have long-lasting negative consequences on oil palm cultivation. Climate change is predicted to make matters considerably more challenging in the ensuing decades. Significant losses are caused by floods and flash floods, which are frequent in Malaysia during times of continuous rainfall (**Safiah Yusmah *et al.*, 2020**). The east coast states of Peninsular Malaysia, including Kelantan, Terengganu, Pahang, and Western Sarawak, frequently face flooding during the northeast monsoon season (**Buslima *et al.*, 2018**). About 4.82 million people in Malaysia are impacted by flood disasters, which are expected to affect 29,800 km^2 of the country's total geographical area. Poverty and vulnerability are rising as a result of rising flood risk, exposure, and damage potential. Because the flood hazard occurs every year, oil palm growers are forced to make plans in advance to lessen its effects (**Safiah Yusmah *et al.*, 2020**). 1886, 1926, 1931, 1947, 1954, 1957, 1965, 1967, 1970/1971, 1988, 1993, 1996, 2000, 2006/ 2007, 2008, 2009, and 2010 are among the major floods that devastated Malaysia (**Buslima *et al.*, 2018**).

Thousands of hectares of Malaysian forest and plantation were damaged by the storm forest flood in 1926. Due to a lack of nitrogen and sulfur, flooding caused the oil palm fiber (OPF) to turn yellow, which killed off juvenile palms. High water levels in rivers outside the plantation and heavy precipitation within the plantation are the two main causes of flooding in plantations. An extended period of flooding on a plantation will have a detrimental effect on oil palm yield. **Muhadi *et al.* (2017)** use the Average Recurrence Interval (ARI) 10 ARI, 50 ARI, and 100 ARI scenarios to forecast flood damage in Malaysian oil palm agricultural zones.

The low flood tolerance of oil palm is predicted to get worse as climate change progresses. Furthermore, 42% of Sarawak's present oil palm plantations and many other oil palm-growing regions will experience a rise in flood issues, and plantation drainage would decline by 56% in 2059 and 82% by 2109 (**Giesen and Nirmal, 2018**). According to projections, planation drainability in oil palm areas that are often flooded by high water levels will drop to 18% by 2009, 27% in 2034, 39% in 2059, and 64% in 2109. As projected, floods will become more frequent in Sarawak and plantations will become less productive as groundwater table levels decline. It is anticipated that oil palm production will have long since decreased before the nearly constant floods. The vast majority of Sarawak's plantations will eventually stop producing; this will happen in decades for a significant percentage and during the next century for the majority of the current farmed areas. In 2014, almost 1.02 million hectares of oil palm plantations were impacted by lowland floods in the east coast states of Kelantan, Terengganu, and Pahang. According to official Malaysian government figures, the overall production of oil palm in Peninsular Malaysia fell by 230,000 tonnes in 2013, while floods caused the country's total production to drop by half a million tonnes in 2014. In 2021, Sarawak's yields are predicted to have decreased by 15% to 20% (**The Star, 2021**).

Oil Palm Adaptation and Mitigation to Climate Change

Multiple efforts are requested from the social, political, economic, educational, environmental, and technological sectors in order to address climate change. Water, coastal, and marine resources, agriculture, biodiversity, forestry, public health, and energy are among the susceptible areas that require adaptation and planning to lessen the effects of climate change (**Tang, 2019**).

Mitigation strategies to climate change

Mitigation methods are needed to lessen the current effects of climate change on oil palm, which have caused losses for farmers, and achieve sustainable output (**Sarkar *et al.,* 2020 and Ahmed *et al.,* 2021**). In order to adapt to and lessen the effects of climate change, the Malaysian government implemented a national policy on the subject in 2009 (**Rao and Mustapa, 2021**). By focusing on important economic sectors, the Eleventh Malaysia Plan (2016–2020) aims to achieve sustainable green growth through the conservation of the environment and the sustainable use of natural resources. The agro-food sector can be safeguarded and a certification program for sustainable agricultural practices can be started by controlling GHGs, particularly methane, through biogas collection and sustainable milling processes (**MNRE, 2015 and Tang, 2019**). Carbon pool conservation, efficient management of tropical forest biodiversity and soil carbon storage, sustainable agricultural and soil management techniques, zero tillage to reduce soil and fauna carbon loss, low encroachment rate, and maintaining dense carbon forest reserve areas and ecosystems are some of the mitigation strategies (**Paterson and Lima, 2018 and Sarkar *et al.,* 2020**). Strict laws against careless tree-cutting are another mitigation tactic, as is encouraging afforestation to help preserve soil and ground biomass cover to improve carbon sequestration (**Raihan *et al.,* 2019 and Sarkar *et al.,* 2020**). Intensifying crop production through organic and smart agriculture is another option mentioned.

Adaptation to climate change

In addition to raising awareness of new plantation management strategies and sustainable pest and disease control measures, the government (at all levels) and non-governmental organizations (through extension agencies) should provide farmers with practical information about oil palm. Increasing the extension service agents' capacity, expertise, and knowledge makes it easier to adapt to climate change (**Zikhali *et al.,* 2020; Antwi-Agyei and Stringer, 2021**). More research should examine the effects of oil palm on climate change and adaptation to new farming **m**ethods **(Irawan and Syakir, 2019; Man *et al.,* 2019**). Researchers are tasked with developing oil palm varieties that are more resilient to climate change, developing innovative water-saving methods to reduce infiltration, and implementing practical strategies to reduce pest and disease infestation (**Irawan and Syakir, 2019**).

One promising strategy for climate change adaptation is the management of soil and water conservation on plantations. To improve water infiltration and reduce runoff, a silt pit positioned perpendicular to the slope collects runoff water and circulates it throughout the plantation (**Lei *et al.,* 2020**). By employing bench terrace mechanisms and silt pit procedures, surface runoff could be decreased by 71.49–74.36% and 79.41–99.0%, respectively. According to **Sarker *et al.* (2020),** the two methods could increase the soil's capacity to retain water by 134.0–141.25 mm and 165.11–201.0 mm, respectively.

In oil palm plantations, intercropping between rows of crops like legumes and cereals can boost farmers' incomes and enhance food security in the event of climate uncertainty (**Khasanah *et al.,* 2020**). In oil palm plantations, mulching is a useful technique for preserving soil moisture (**Iqbal *et al.,* 2020**). Mulching improves the water-holding capacity and soil structure (**Ngangom *et al.,* 2020; Amare and Desta, 2021**). Oil palm plantations have implemented a number of environmentally friendly and agroecological techniques to increase soil fertility, reduce evapotranspiration, and conserve soil (**Ahmed *et al.,* 2021**). These methods include using environmentally safe and sustainable fertilizer, keeping an eye on the size of the OPF, and having a very capable management staff (**Ahmed *et al.,* 2021**). According to reports, oil palm trees that are young should have 48–56 fronds, while those that are mature should have 40–48 fronds (**Nabara and Man, 2018**). Pruned OPFs can be put on the surface to increase soil fertility after decomposition by reducing evaporation. One viable method for conserving soil and water in oil palm plantations is the use of oil palm by-products such OPF and EFB. In addition to producing enormous amounts of biomass waste, 96% of the dry matter from oil palm above ground is recycled into different plantations, which, when they break down and decompose, can be used as mulch or to increase soil fertility (**Nabara and Man, 2018 and Ojemade *et al.*, 2019).**

After taking into account future farming technology and the quick changes in technology, which may affect adaptation alternatives, sustainable adaptation planning should be comprehensive (**Stringer *et al.*, 2020 and Sarkar *et al.*, 2020**). Food security and sustainable ecosystem management (**Iglesias and Garrote, 2018 and Amjath-Babu *et al.*, 2018**), land tenure and fragmentation, a variety of technological options, sustainable water management, capacity building, and livelihood diversification should all be taken into consideration in these adaptation strategies in order to support adaptive capacity (**Naqvi *et al.*, 2020**). Political will and commitments are needed to implement these strategies, which include: reexamining and revitalizing market, agricultural, and water policies; research and development; training farmers and extension workers; providing farmers with subsidized credit; and maintaining market supply in spite of climate change (**Gruda *et al.*, 2019; Paterson and Lima, 2018 and Sarkar *et al.*, 2020**).

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أثر درجة الحرارة والأمطار والفيضانات على إنتاج نخيل الزيت فى ماليزيا – دراسة مرجعية

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لقد أصبحت الفيضانات وهطول الأمطار ودرجات الحرارة كلها تهديدات بيئية رئيسية. وتشير نتائج هذه الدراسة إلى أن إنتاج زيت النخيل تأثر سلبًا بدرجات الحرارة وهطول الأمطار والفيضانات وسيستمر في التأثر بذلك. وكما يمكن إظهاره، فإن ظاهرة النينيو والفيضانات في عامي 1997-1998 و2015-2016 أدت إلى انخفاض كبير في معدل دوران غلة زيت النخيل من خلال تغيير نمط الطقس العام والتأثير على فسيولوجيا التربة والنبات. وكان من المتوقع أن يؤدي ارتفاع درجة الحرارة بمقدار 1-4 درجات مئوية إلى انخفاض بنسبة 10-41% في غلة زيت النخيل في ماليزيا، مما يدل على التأثيرات الكبيرة لارتفاع درجات الحرارة المتوسطة على إنتاجية زيت النخيل. تؤدي درجات الحرارة المرتفعة إلى تفاقم معدل التبخر، مما يؤدي إلى جفاف التربة وزيادة الإجهاد المائي، مما يؤدي في النهاية إلى تباطؤ النمو وانخفاض الغلة. بالإضافة إلى جعل الأيام أكثر دفئًا والليالي أكثر برودة، فإن ارتفاع درجات الحرارة يغير من بيئة عدد من الأمراض والآفات. وبسبب زيادة أعدادها وزيادة قدرتها على التكيف مع بيئتها المتغيرة، فإن هذه الآفات والأمراض لديها القدرة على الانتشار عبر المزارع والتسبب في وباء أو ربما جائحة. وقد تعوق عملية التلقيح الحشرات الملقحة التي تتعرض لهجوم من قبل كائنات حية أخرى، مما قد يؤدي إلى انخفاض أعدادها. بالإضافة إلى التوزيع الإقليمي الأوسع والظروف الأكثر جفافًا المتوقعة خلال موسم الرياح الموسمية الجنوبية الغربية نحو نهاية القرن الحادي والعشرين، أظهرت توقعات هطول الأمطار هطول أمطار غزيرة حول الأعوام 2081-2100. ومن أجل معالجة آثار درجات الحرارة وهطول الأمطار والفيضانات على إنتاج نخيل الزيت، تقدم الدراسة التوصيات السياسية التالية: تحسين التنوع، وتحسين البحوث المؤسسية، والتعاون بين البلدان المنتجة والبلدان المستهلكة الرئيسية في مجال البحوث، ونقل التكنولوجيا، والتعليم البيئي، ومهارات الإدارة، وخدمات الإرشاد لمزارعي نخيل الزيت؛ وسياسة الاستخدام المستدام للأراضي والتوسع دون إزالة الغابات؛ وسهولة الوصول إلى النتائج الأكاديمية، والاتصال بها، وتوافرها.

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