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Potential Risks of Climate Change to Oil Palm Cultivation in Malaysia

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This desktop study evaluates the potential risks of climate change in Malaysia on oil palm cultivation in the field up to the year 2050. Increasing carbon dioxide (CO_2) level in the atmosphere has a positive effect on oil palm performance. However, the oil palm is unable to use this positive effect to its maximum due to the higher air temperatures and uneven rainfall patterns that come with climate change. Higher air temperatures during frequent low rainfall periods subject the oil palm to water and heat stress which reduce photosynthesis. In addition, during the subsequent heavy rainfall periods, the solar radiation is low and reduces photosynthesis. The heavy rainfall also causes flooding of river basins and coastal regions; posing problems to fresh fruit bunch (FFB) harvesting and crop evacuation. If the land is flooded for long periods, it will also become unsuitable for planting oil palm. A rising sea level with climate change also results in the intrusion of saline sea water into coastal areas. This poses challenges for oil palm cultivation since the crop does not tolerate saline conditions. Climate change is also found to favour higher risk of attacks on oil palm by pests and diseases. In conclusion, the climate of Malaysia is still suitable for oil palm cultivation up to 2050 in spite of climate change. However, climate change presents risks to oil palm cultivation; the magnitude depending on its severity.

Keywords*: Climate change, water and heat stress, flooding, sea level rise, oil palm cultivation , pests and diseases.*

The tropical environment is suitable for the cultivation of oil palm. In Malaysia, the oil palm industry celebrated its centenary in 2017 and is 104 years old now. The country has soils and climate which are found to be generally suitable for the cultivation of the crop.

Soils and climate are the two resources that determine the primary external factors *viz.* light, air temperature, carbon dioxide (CO_2), water and nutrients that influence oil palm cultivation. Between these two primary resources, the soils have been improved *via* better agro-management practices, especially fertiliser applications, in order to get higher oil palm productivity in the field.

Climatic features such as light, temperature, rainfall amount and distribution cannot be manipulated on a large scale for oil palm production over the long-term. In fact, oil palm is a tropical crop and highly dependent on suitable weather conditions for high productivity. For example, almost all oil palm areas are rainfed. As such, it is useful to know the possible risks involved with climate change on oil palm cultivation and this topic serves the purpose of this paper.

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The aims of the study are as follows:

i. Find out the possible climate change scenario (s) for Malaysia, and
ii. Determine the risks of climate change on oil palm cultivation based on the climate change scenarios projected.

METHODOLOGY OF THE STUDY

This is a desktop study based on a search of literature.

The official climate change scenario for Malaysia up to the year 2050 is obtained from Malaysia's Third National Communication and Second Biennial Update Report; commonly referred to as NC3 in short (MESTECC, 2018). This is the country's latest submission to the United Nations Framework Convention on Climate Change (UNFCCC). The parameters of mean annual air temperature, mean annual rainfall and sea level rise are obtained from this report. According to the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) (2018) the future projections of the first two parameters were obtained by using a Regional Hydro-Climate Model (Reg HCM) in combination with Global Climate Models (GCMs) while sea level rise projections were based on dynamic modelling whereby the flood extents were based on projected river flows of major rivers in the country.

The other climatic parameters such as CO_2 levels, maximum mean daily temperatures and solar radiation are not provided in NC3. They are obtained or extrapolated from sources which are mentioned in the relevant sections.

The cultivation of oil palm for this study refers to the field operations, growth and productivity of the crop. The evaluation of the impacts of climate change on oil palm cultivation are based on the current practices in the palm oil industry. Since climate change projections are made into the future, new technologies for oil palm cultivation not used or found in the literature search, are not used in this study.

An evaluation of the impacts or risks of climate change on the cultivation of oil palm is then carried out. It is pointed out that research on impacts of climate change on oil palm performance and disease incidences e.g. *Ganorderma* are still in an infant stage in Malaysia. As an emerging science, such impacts have often been studied by simulation with the use of models. Thus, such predictions of outcomes are theoretical and indicate possible risks rather than actual outcomes.

RESULTS AND DISCUSSIONS

The results are presented as follows.

Climate change in Malaysia

Climate change, in the form of global warming, has been detected in Malaysia. Global warming is a phenomenon whereby the world gets warmer and results in the atmospheric temperature increasing with time. A study on the mean daily temperatures from 1969 to 2014 or a 46-year period shows that the temperature of Malaysia has been increasing. The mean air temperature has increased between 0.13 - 0.24°C while mean maximum and minimum temperatures have also increased by 0.17 - 0.23°C and 0.19 -0.30°C per decade respectively over the same period (MESTECC, 2018). The average mean, maximum and minimum air temperatures have thus increased by 0.19°C, 0.20°C and 0.25°C per decade respectively. The days are getting hotter and the nights are also warmer.

Projected climate change scenarios

The observed values of annual air temperature, annual rainfall and sea level rise for Sabah, Sarawak and Peninsular Malaysia obtained from NC3 are given in the following subsections. The projected values of these parameters for 2030 and 2050 are also given.

Annual air temperature

From the results in *Table 1*, the mean annual air temperature will be expected to increase to 26.3°C in 2030, with the largest increase of 26.7°C found in Peninsular Malaysia and the lowest increase of 26.2°C found in Sarawak according to MESTECC (2018). In 2050, the mean annual air temperature will increase by another 0.7°C to reach 27.0°C. Overall for Malaysia, the mean annual air temperatures can increase by 0.7-0.8°C in 2030 and by 1.4°C in 2050. While the variation in range of observed mean annual temperatures for the period of 1970-2000 were between 1.1°C and 1.4°C for the three regions, the variation of the projected temperatures are much higher; these being 1.2-1.6 °C and 1.1-1.7 °C in 2030 and 2050 respectively. For the period between 2030 and 2050, the lowest variation is seen in Sarawak and the largest variation in Sabah.

Annual rainfall

Mean annual rainfall is projected to increase to 3 022 mm in 2030 and 3 068 mm in 2050 as shown in *Table 2*. The rainfall will increase by 1.6 per cent and 3.2 per cent in 2030 and 2050 respectively when compared to the long-term mean rainfall of 2 973 mm.

While all regions of Malaysia will receive more rainfall up to 2050, an exception is found for Sabah in 2030, when the climate models projected lower rainfall for this region. Variation in the range of rainfall amounts for the period of 1970-2000 are lowest for Sarawak (356 mm) followed by Peninsular Malaysia (800 mm) while the largest variation is found in Sabah (1 268 mm). This order is again repeated for the three regions in 2030 with rainfall amounts varying by 547 665 mm and 1 054 mm respectively. A similar pattern in the variation of rainfall amounts for these three regions is repeated in 2050, with 550 737 mm and 1 265 mm respectively.

Sea level rise

During the period of 1970-2000, the sea level has risen the most for Sabah, followed by Peninsular Malaysia and Sarawak with 6.03 mm, 4.59 mm and 4.47 mm per year

TABLE 1
OBSERVED AND PROJECTED MEAN ANNUAL AIR TEMPERATURES FOR DIFFERENT REGIONS OF MALAYSIA UP TO 2050

Region	*Mean and range of annual air temperatures (°C)*		
	Observed (1970-2000)	*Projected for 2030*	*Projected for 2050*
Peninsular Malaysia	26.0 (25.4-26.5)	26.7 (26.0-27.4)	27.4 (26.6-28.1)
Sabah	25.2 (24.3-26.1)	26.1 (25.3-26.9)	26.6 (25.7-27.4)
Sarawak	25.5 (24.8-26.2)	26.2 (25.6-26.8)	27.0 (26.4-27.5)
Mean of means	25.6 (24.8-26.3)	26.3 (25.6-27.0)	27.0 (26.2-27.7)

Note: Range of annual air temperatures (°C) are provided within brackets
Source: adapted from MESTECC (2018)

TABLE 2
OBSERVED AND PROJECTED MEAN ANNUAL RAINFALLS FOR DIFFERENT REGIONS OF MALAYSIA UP TO 2050

Region	*Mean annual rainfall (mm)*		
	Observed(1970-2000)	*Projected for 2030*	*Projected for 2050*
Peninsular Malaysia	2 291 (1 891-2 691)	2 331 (1 998-2 663)	2 437 (2 068-2 805)
Sabah	2 898 (2 264-3 532)	2 865 (2 338-3 392)	2 917 (2 284-3 549)
Sarawak	3 729 (3 551-3 907)	3 871 (3 597-4 144)	3 849 (3 574-4 124)
Mean of means	2 973 (2 569-3 377)	3 022 (2 644-3 400)	3 068 (2 642-3 493)

Note: Range of mean annual rainfalls (mm) are provided within brackets
Source: adapted from MESTECC (2018)

respectively in the period of 1970- 2000 as seen in *Table 3*. The mean sea level will continue to rise in Peninsular Malaysia by 70 cm and 160 cm in 2030 and 2050 respectively. A higher sea level rise will be expected in the west coast than in the east coast of Peninsular Malaysia. Sarawak will experience similar mean sea level rises of 80 cm and 190 cm during the same periods. The largest mean sea level rise amounting to 130 cm and 420 cm will be expected in Sabah in 2030 and 2050 respectively.

Climate suitability for oil palm cultivation

The criteria of climate suitability for oil palm cultivation are obtained from Goh (2000) and shown in *Table 4*. The best conditions for oil palm cultivation are an annual rainfall amount of 2 000-2 500 mm per year, no dry months,

TABLE 3
OBSERVED AND PROJECTED MEAN SEA LEVEL RISE FOR DIFFERENT REGIONS OF MALAYSIA UP TO 2050

Region		*Mean (range)*		
		Observed rate (mm/year) (1970-2000)	*Projected for 2030 (m)*	*Projected for 2050 (m)*
Peninsular Malaysia	Mean	4.59 (2.73-6.45)	0.07 (0.03-0.10)	0.16 (0.11-0.21)
	West Coast	Not available	0.08 (0.05-0.10)	0.16 (0.11-0.21)
	East Coast	Not available	0.05 (0.03-0.07)	0.13 (0.11-0.15)
Sabah		6.03 (5.06-7.00)	0.13 (0.11-0.15)	0.42 (0.21-0.62)
Sarawak		4.47 (3.82-5.11)	0.08 (0.04-0.12)	0.19 (0.15-0.22)

Source: adapted from MESTECC (2018)

TABLE 4
CLIMATE SUITABILITY FOR OIL PALM CULTIVATION

Parameter	*Highly suitable*	*Suitable*	*Moderately suitable*	*Currently unsuitable*	*Permanently unsuitable*
Annual rainfall (mm)	2 000-2 500	2 500-3 000 1 750-2 000	3 000-4 000 1 400-1 700	4 000-5 000 1 100-1 400	>5 000 <1 100
Duration of dry season (months)	0	1	2-4	5-6	>6
Mean annual temperature (^{o}C)	26-29	29-32 23-26	32-34 20-23	34-36 17-20	>36 <20
Daily solar radiation (MJ/m^3)	16-17	17-19 14-16	19-21 11-14	21-23 8-11	>23 <8

Source: Goh (2000)

mean annual temperature of 26-29^{o}C and a daily solar radiation of 16-17 MJ per cubic metre. Harun *et al*. (2009) also mentioned that the oil palm needs 5-7 hours of direct sunlight per day with low cloud covers during the daytime.

Risks of rising CO_2 content in atmosphere on oil palm cultivation

NC3 did not provide any projections for CO_2 content in the atmosphere for Malaysia. This is due to the fact that this measurement is not done on a routine basis for the country. As such, projections of atmospheric CO_2 for the country have to be extrapolated from other studies.

The concentration of CO_2 in the atmosphere in the world was 400 ppm in 2014 and is projected to reach between 600-1 000 ppm by 2100 (Watson *et al*., 1990). While the amount of CO_2 in the atmosphere has increased over the years, the annual rate of increase has also increased. It was 1.5 ppm per year in the 1980s and 1990s but this has gone up to 2 ppm per year for the period of 2006-2015. In 2015, the annual CO_2 increase was 3 ppm per year (Butler & Stephan, 2016). By using the latest scenario of a CO_2 increase of 3 ppm per year, it is, thus, projected for this study that CO_2 concentration will be 448 ppm in 2030 and 508 ppm in 2050 for Malaysia.

Higher atmospheric CO_2 concentrations boost crop yields by increasing the rate of photosynthesis. In fact, Gaastra (1962) found that, generally, plant photosynthetic rate increases three times with a four-fold increase in CO_2 concentration.

An increased CO_2 concentration was also found to increase oil palm growth. When CO_2 concentration was increased from 400 ppm to 800 ppm for a period of 15 weeks, oil palm seedling biomass increased by 112 per cent. There was no difference for three *tenera* oil palm progenies in their response to CO_2 concentration enrichment (Harun *et al.*, 2009; Shahabuddin *et al*., 2011). The former authors also reported that by using the OPRODSIM (Oil Palm Production Simulator) model, they predicted that doubling of CO_2 concentration would increase fresh fruit bunch (FFB) yield by 128 per cent on coastal soils and 80 per cent on inland soils.

An increase in CO_2 levels due to climate change has a positive effect on plant growth and yield if the other factors *viz* light, temperature and air humidity are not limiting. (https://www.toppr.com/contnet/concept/). There are two situations when the positive effect of an increasing CO_2 content on better performance of oil palm are reduced due to climate change. The first situation happens when a higher air temperature also increases the intensity of heat and water stress conditions for the oil palm. This condition leads to a lowering of plant photosynthesis and reduces the positive effect of higher atmospheric CO_2 levels. This may happen in a situation of low rainfall periods and particularly in soils with low water holding capacity e.g. lateritic and sandy soils. While the use of anti-transpirants has been found to be helpful for oil palm to manage heat and water stress (Yew *et al.,* 2015), its use comes with an additional cost.

The second possible situation happens when the intense dry season alternates with periods of heavy rainfall. During the rainy period, lower solar radiation is encountered and results in lower photosynthesis. It is, thus, speculated that the positive effect of an increased CO_2 content in the atmosphere will not be significant as its positive effect will be reduced by these two annual environmental conditions that come with climate change.

Risks of temperature change on oil palm cultivation

The evaluation of temperature *per se* to determine its suitability for oil palm cultivation is shown in *Table 5*. This is done by comparing the temperatures obtained in *Table 1* with its suitability for oil palm cultivation in *Table 4*. Even though the temperatures are higher for all the regions in Malaysia up to 2050, they are still considered to be highly suitable to suitable for oil palm cultivation based on this evaluation.

Another study by Paterson *et al.* (2015) has projected that the air temperature in 2050 will rise to 27.5-28°C. This is still considered to be highly suitable for oil palm cultivation according to the criteria of Goh (2000).

Temperature affects plant transpiration and photosynthesis processes by regulating its stomatal behaviour. When the air temperature increases, the plant canopy becomes hotter and leaf vapour pressure deficit (VPD) increases leading to a higher rate of plant transpiration, stomatal closure and decreasing the water use efficiency of the plant (Jalota *et al.,* 2018). The warmer environment also accelerates leaf maturation and senescence. These combined factors decrease the duration of active photosynthesis.

The unfavourable risks of a high temperature on crop productivity can be overcome by an increase in precipitation. As

TABLE 5
AIR TEMPERATURES IN DIFFERENT REGIONS OF MALAYSIA AND THEIR SUITABILITY FOR OIL PALM CULTIVATION UP TO 2050

Region	*Expected range of mean air temperature (°C)*	
	Year 2030	*Year 2050*
Peninsular Malaysia	26.0-27.4 (highly suitable)	26.6-28.1 (highly suitable)
Sabah	25.3-26.9 (suitable to highly suitable)	25.7-27.4 (highly suitable)
Sarawak	25.6-26.8 (highly suitable)	26.4-27.5 (highly suitable)

an example, the adverse effect of a yield decrease in wheat due to a rise of 1-2 °C was offset by a 5-10 per cent increase in precipitation based on a study in India (Abrol *et al.*, 1991).

The maximum air temperature in the day has a greater effect on yield reduction than mean air temperature. Jalota *et al*. (2009) found that the beneficial increase in yields of rice by doubling CO_2 concentration from 380 ppm to 760 ppm was levelled off by increasing the maximum air temperature by 1.1 °C.

The results in *Table 6* show that the mean daily maximum air temperatures can differ from the mean daily temperatures by as much as 5.5°C in Peninsular Malaysia; these averaging 31.8°C and 26.3°C respectively based on a study by Yew and Sys (1990).

The projected mean daily temperatures for Malaysia will be 26.3°C in 2030 and 27.0°C in 2050 (MESTECC, 2018). It is postulated in this study that daily maximum temperatures will possibly reach 31.8 °C in 2030 and 32.5°C in 2050. Based on the findings of Rahutomo (2018), the optimal maximum air temperature for oil palm cultivation is 29-33°C. Thus, these maximum air temperatures are not a problem for oil palm cultivation. Moreover, the daily maximum temperatures in an oil palm ecosystem is expected to be lower than that in the town areas. Thus, the mean daily maximum temperatures of the oil palm ecosystem will be expected to be lower than 31.8-32.5°C and should not pose a problem for oil palm cultivation.

Risks of rainfall and drought on oil palm

NC3 projected that in 2030, Sarawak will have the highest rainfall followed by Sabah and Peninsular Malaysia; with total annual rainfalls of 3 871 mm, 2 865 mm and 2 331 mm respectively as seen in *Table 7*. The same trend of higher mean total annual rainfalls ranging from 2 437 mm to 3 849 mm for these regions will continue into 2050.

The rainfall amounts of 2 331 mm in 2030 and 2 437 mm in 2050 in Peninsular Malaysia are considered to be highly suitable for oil palm cultivation. The higher rainfalls between 2 865 mm and 2 917 mm projected for Sabah during this period are also considered to be suitable for the crop. However, the very high rainfalls in Sarawak ranging from 3 871 - 3 849 mm during this period are considered to be only moderately suitable for oil palm cultivation.

TABLE 6
AVERAGE MEAN AND MAXIMUM TEMPERATURES IN SIX LOCATIONS IN PENINSULAR MALAYSIA

Location (town, state)	*Mean daily temperature (°C)*	*Mean daily maximum temperature (°C)*
Alor Setar, Kedah	26.9	32.3
Ipoh, Perak	26.7	32.7
Kuala Lumpur, Selangor	26.3	32.0
Melaka	26.4	31.4
Johor Baru, Johore	25.7	31.0
Kuantan, Pahang	25.8	31.2
Mean of means	26.3	31.8

Source: Yew and Sys (1990)

TABLE 7
TOTAL ANNUAL RAINFALL IN DIFFERENT REGIONS OF MALAYSIA AND ITS SUITABILITY FOR OIL PALM CULTIVATION UP TO 2050

Region		*Total annual rainfall (mm)*	
		Year 2030	*Year 2050*
Peninsular Malaysia	Mean	2 331 (highly suitable)	2 437(highly suitable)
	Range	1 998-2 663 (highly suitable to suitable)	2 068-2 805 (highly suitable to suitable)
Sabah	Mean	2 865 (suitable)	2 917 (suitable)
	Range	2 338-3 392 (highly suitable to moderately suitable)	2 284-3 549 (highly suitable to moderately suitable)
Sarawak	Mean	3 871 (moderately suitable)	3 849 (moderately suitable)
	Range	3 597-4 144 (moderately suitable to currently unsuitable)	3 574-4 124 (moderately suitable to currently unsuitable)

Source: MESTECC (2018)

An evaluation of rainfall suitability for oil palm cultivation based on the expected range of rainfall in the regions shows the same trend whereby Peninsular Malaysia is highly suitable to suitable for oil palm cultivation. Due to the large variability of rainfall in Sabah, the state is still considered to be highly suitable for oil palm cultivation when the rainfall is 2 284 mm and lower. If rainfall exceeds 3 000 mm, Sabah will then be classified to be moderately suitable for oil palm cultivation due to high rainfall related issues such as flooding, loss of harvesting days, low solar radiation, etc. Sarawak will be expected to receive 3 574 mm to 4 144 mm rainfall annually between 2030 and 2050 and is rated to be moderately suitable to unsuitable for oil palm cultivation based on the consideration of rainfall only. Rainfall pattern has a direct impact on oil palm performance. Chow (1991) found that oil palm production was correlated with low rainfall at lags of 10-11 months and 20-24 months before FFB harvest. He also found adverse effects of excessive rainfall on anthesis and pollination.

Rainfall quantity and its distribution within the year also determine the length of sunshine hours and the severity of the dry season. During rainy days, the number of sunshine hours are reduced. Since oil palm thrives best in areas with 5-7 hours of sunshine with solar radiation exceeding 5 MJ per square metre daily (Hartley, 1988; Goh, 2000), the reduced solar radiation affects oil palm growth and yield negatively. The importance of high solar radiation on oil palm productivity has also been stressed by Chan (1991). It is, thus, envisaged that excessive rainfall due to climate change e.g. as seen in Sarawak will not provide the ideal conditions for oil palm cultivation.

According to the Intergovernmental Panel on Climate Change (IPCC) (2014), weather conditions will become more extreme as a consequence of climate change. Uneven distribution of rainfall during the year is a common feature in the rainfall pattern for Peninsular Malaysia, with some months of the year receiving heavy rainfall while other months of the year have low rainfall amounts (Dale,1959). This uneven distribution of rainfall results in a differentiation of the dry and wet seasons. With climate change, a higher quantity of rainfall will be expected. If this weather pattern of alternating dry and wet seasons continues and the weather conditions of IPCC, 2014 are to be followed, it is likely that the amount of precipitation during the rainy periods will be much higher than that obtained presently. Similarly, the dry periods will get drier in the future and will cause the soil moisture deficit during these periods to be larger. Such weather of very high rainfall periods alternating with severe droughts are not ideal for oil palm growth and production resulting in water stress conditions which will be more pronounced on lateritic and sandy soils due to their low water holding ability.

In fact, MESTECC (2018) projected that dry spells will occur more frequently in the future. This happens since the rainfall will be unevenly distributed even though rainfall amounts will increase as a result of climate change. The end result will be that very dry seasons will alternate with seasons with very heavy rainfalls. One to two dry spells will occur in Peninsular Malaysia while two to four dry spells will occur for Sabah and Sarawak. The report also mentioned that severe dry spells will occur between 2025 to 2035 in Peninsular Malaysia while they will be expected to happen in Sabah and Sarawak in 2045-2055. It is, thus, seen that such an uneven distribution of rainfall is not conducive for good cultivation of oil palm. An even distribution of rainfall throughout the year is ideal but does not happen with climate change.

The exceptionally high rainfall will lead to more flooding in the low lying areas and hinder crop harvesting and evacuation. The flooded fields also prevent important field operations e.g. manuring to be carried out on time. While oil palms are quite tolerant of flooding, long-term stagnant flooded conditions can impair oil palm growth and result in plant mortality (Corley & Tinker, 2003).

The importance of having sufficient water for good growth and productivity of oil palm is well known. The oil palm when affected by prolonged water stress has multiple unopened spears and even premature frond fracture and desiccation that leads to a reduction of leaf area for photosynthesis. Prolonged water stress increases male inflorescence production and reduction in the sex ratio with a subsequent drop in FFB production 19-22 months later (Harun *et al.*, 2009). Very severe droughts may also cause the emerging female inflorescences to abort. A sufficient supply of water is also needed during fruit ripening and to form fruit bunches with high FFB yields according to these authors.

Climate change may also cause *El Ninos* to become more intense. Since drought is a feature of *El Ninos*, oil palm yields will be depressed. This was seen during the 2014-2016 *El Nino* when FFB yields in Peninsular Malaysia dropped by 21 per cent in comparison to the non *El Nino* yields (Mohd. Nasir *et al.*, 2017). The authors also found a larger 35 per cent decrease in yield in East Malaysia during this *El Nino*.

Risks of rising sea level and flooding

MESTECC (2018) projected that sea level will rise between 0.05-0.15 m by 2030 for the three regions in Malaysia (*Table 8*). By 2050 sea level will rise higher by 0.11- 0.62 m. Sea level rise will be highest in Sabah while Sarawak and Peninsular Malaysia will have similar increases in sea level. MESTECC also

TABLE 8
PROJECTED SEA LEVEL RISE IN MALAYSIA UP TO 2050

Region	*2030*	*2050*
Peninsular Malaysia	0.05-0.10 m	0.11-0.21 m
Sabah	0.11-0.15 m	0.21-0.62 m
Sarawak	0.04-0.12 m	0.15-0.22 m
Average	0.07-0.12 m	0.16-0.35 m

Source: MESTECC (2018)

projected that sea level rise will be higher in the West Coast of Peninsular Malaysia, inclusive of South Johor while that in the East Coast will be lower. It is, thus, expected that intrusion of sea level into the coastal areas in all the three regions of Malaysia will take place.

Sea level rise may cause some areas to be flooded and render them unsuitable for oil palm cultivation if they are flooded for long periods of time. However, if they are flooded for short periods of time, oil palm cultivation may require the fields to be drained. Besides, oil palm is sensitive to saline conditions and intrusion of sea water will pose a serious problem to the crop (Ahmad, 1993). Corley (2016) pointed out that it will still be possible to grow oil palm close or even below the high sea level but costs of bunding and good drainage and/or pumping out the water may make such areas uncompetitive if good yields cannot be realised.

Apart from sea level rise which will impact coastal areas the most, MESTECC also (2018) projected that flood prone oil palm cultivation areas will almost double by 2030 and increase by 5.6 times in 2050 in Peninsular Malaysia alone as shown in *Table 9*. In 2015, about 68 500 hectares of oil palm growing areas were situated in flood prone areas but this area will increase to almost twice to six-fold by 2030 and 2050 respectively. It is expected that Sabah

TABLE 9
HECTARAGE OF FLOOD PRONE OIL PALM GROWING AREAS IN PENINSULAR MALAYSIA UP TO 2050 DUE TO CLIMATE CHANGE

State	*Area (ha)*		
	Year 2000	*Year 2030*	*Year 2050*
Johor	20 909	44 642	102 191
Melaka	2 062	2 381	2 410
Selangor	5 366	10 945	31 400
Perak	7 741	9 047	9 487
Kedah	3 234	9 738	54 534
Kelantan	6 619	21 081	135 005
Terengganu	412	1 228	20 111
Pahang	22 186	27 535	29 137
Total	68 529	126 597	384 275

Source: MESTECC (2018)

and Sarawak will also be affected but the results are not available in NC3. The increasing hectarage of flooded oil palm over the years will mean a greater loss of area for cultivating oil palm if water remains stagnated. Otherwise, there will be the risk of loss of crop due to the inability to harvest and evacuate FFB effectively if water stagnation is not permanent.

Risks on pests and diseases

Pests and diseases reduce the optimal performance of oil palm; such pestilences coming from animals, insects and fungi. Some common oil palm pests include rats, rhinoceros beetles and bagworms while *Ganoderma* is a dreaded oil palm disease. *Ganoderma* used to infect old oil palms, exceeding 25 years of age, when it was first reported in Malaysia (Thompson, 1931) but it is now found to infect oil palms as young as 12-24 months after planting (Singh, 1991).

Ganoderma is found to thrive in different soil situations. Singh (1991) found higher incidence of *Ganoderma* on coastal soils and suggested that the higher soil moisture content might favour the prevalence of this fungus over other antagonistic fungi. However, Flood *et al.* (2010) has reported its presence in inland lateritic soils which have low soil moisture contents while Idris (2007) mentioned that it is also found in peat soils.

It is generally well accepted that good phytosanitary field practices, minimising root contact and use of fungicides are the main methods for disease management and controlling its spread (Corley & Tinker, 2003; Idris, 2007; Idris *et al.*, 2013). While the general consensus is that the disease is spread principally through root contact, there is indication to show that the disease can also be spread by spores (Flood *et al.*, 1998, Pilotti & Sanderson, 2001 as mentioned by Corley & Tinker, 2003).

Climate plays an important role in the epidemiology of plant diseases and the life cycle of animal and insect pests. As an example, Corley and Tinker (2003) mentioned the research of Ochoa and Bustamante (1974) who found that high air humidity and low light intensity were favourable conditions for *Fusarium moniliforme* for spear rot in African palms. This condition of high air humidity and low light intensity is associated with heavy rainfall periods in Malaysia (Yew, 1982). As heavier rainfalls are expected with climate change, such conditions favour the multiplication of the inoculum and spread of oil palm diseases.

Moreover, the extreme weather conditions in the form of very heavy downpours which lead to flooding and the very prolonged droughts subject the oil palm to physiological stress. In such situations, when oil palm is stressed, it is more prone to attacks by plant diseases including *Ganoderma* (Darus *et al.*, 2000). It is, thus, speculated that the prevalence of *Ganoderma* and other plant diseases will increase with climate change. According to Paterson *et al*. (2015), climate change is expected to weaken the resistance of oil palm to disease infection that includes *Ganoderma* with the possibility of the emergence of new diseases.

In another study, Paterson (2019[1]) hypothesised that the more unsuitable climate will lead to concomitant increases in basal stem rot (BSR) caused by *Ganoderma*. The authors explained that the increase of BSR is caused by the ability of fungi to adapt to climate change quickly while the oil palm is slow to adapt. Based on a study on the projected climate change for Sumatra, Paterson (2019[2]) stated that BSR is predicted to increase dramatically after 2050. In 2100 and onwards, large areas of Malaysia and Indonesia are projected to have an unsuitable climate for oil palm cultivation and BSR will become worse (Paterson *et al*., 2017; Paterson, 2019[2]).

Population dynamics for insects is also related to environmental conditions. Insects generally have shorter development times when air temperatures increase (Assante *et al*., 1991). This has been found to be true for two species of bagworm that were studied, namely *Metisa plana* and *Pteroma pendula* when they had shorter development times and resulted in higher populations at 35°C (Yusof *et al*., 2013). The authors also found that *Pteroma pendula* survived the wet weather better than *Metisa plana* with a surge in population outbreak when the warm and dry season came. This suggests that with climate change in Malaysia higher populations and larger infestations of bagworms, particularly of *Pteroma pendula* species, may be expected.

While some insects cause harm to the oil palm, there are also beneficial insects. The oil palm relies mainly on the weevil *Elaedobius kamerunicus* for pollination. Heavy rainfall and heavy cloud cover will affect pollination by reducing activities of the weevil based on the studies of Sugih *et al*. (1996) in Riau, Indonesia. The pollens are also wet and not in a powdery form that is fit for transference. The net result is that the oil palm fruit set is reduced and leads to lower yields.

On the other hand, high air temperatures, when maximum and minimum temperatures exceeded 35°C and 33° C respectively, were also found to be unfavourable for the multiplication and development of the weevils based on a study in Andhra Pradesh, India (Saravanan *et al.*, 2014). Since both conditions are encountered with climate change, these will be yet possible outcomes.

CONCLUSIONS

Soils and climate are the two main resources that affect oil palm cultivation when the crop is grown under rainfed conditions. The main climatic factors are air temperature, humidity, solar radiation, rainfall and CO_2 concentration.

The NC3 is Malaysia's latest official report of the country's greenhouse gas balance and climate change status. NC3 reported that evidence obtained for a 46-year period from 1969-2014 shows that the mean air temperature in Malaysia has been increasing. The mean air temperature has increased between 0.13-0.24°C per decade for the period studied. Both the mean minimum and mean maximum temperatures of the country have also gone up during this period resulting in hotter days and warmer nights.

NC3 has projected the risks of climate change in Malaysia up to the year 2050 as follows:

- Mean air temperature will increase to 27.0°C, with a range between 26.2 - 27.7°C,
- Total rainfall amount will increase, with an average amount of 3 068 mm per annum and a range between 2 642-3 493 mm,
- Sea level will rise by 0.26 m, with a range of 0.11-0.62 m,
- More frequent extreme weather conditions in the form of excessive rainfall interspaced with extreme dry weather or drought conditions,
- Occurrence of more than one dry period annually,
- Some coastal areas will be flooded and inundated with saline sea water, and
- More river basin areas will become flood prone.

Atmospheric CO_2 concentrations are not given in NC3 since this measurement is not carried out routinely by the Malaysian Meteorological Department, the national organisation that takes measurements of climate parameters for the country. Based on literature review, it is projected that atmospheric CO_2 concentrations for Malaysia will reach 508 ppm by 2050.

An attempt is made to relate the risks of the projected climate change on oil palm cultivation in Malaysia. Oil palm cultivation is mainly rainfed agriculture. The crop depends almost entirely on the existing weather for its growth and production.

While the change of the individual climatic parameters *per se* mentioned above have direct influence on oil palm growth and performance, their actual impacts are the results of interactions of local environmental factors. For example, heavier rainfall that comes with climate change will be beneficial for the cultivation of oil palm in the drier zones of the country. However, if the heavy rainfall is unevenly distributed, this will result in some months with very low rainfall and other months with very heavy rainfall. The interaction of low rainfall with high air temperature will cause severe water and heat stress during this dry period.

Higher atmospheric CO_2 concentration has a positive effect on oil palm growth and yield. However, this positive effect will not be fully realised due to the following two features, namely, the occurrence of more intense and frequent droughts which alternate with the exceptionally heavy rainfalls. Both these situations have dire consequences on photosynthesis and water use dynamics of oil palm.

The higher rainfalls become problematic in parts of the country which already have high rainfall amounts e.g. Sarawak. While the increasing rainfall will be advantageous for oil palm in the drier parts of the country, this may not happen as the rainfall will be unevenly distributed and comes with very rainy periods interspaced with droughts. Intense droughts will become more frequent and pose challenges for growth and production, and depress oil palm yields. Moreover, the heavy rainfalls will probably cause more oil palm in the river basin areas to be flooded. This will stunt oil palm growth and hamper FFB harvesting and evacuation depending on the severity of the flood. The heavy rainfall will also prevent the weevil, *Elaedobius kamerunicus*, from pollinating inflorescences successfully and depress oil palm yields, especially for young oil palm.

There is a relationship between climate change and population dynamics of pests and diseases of oil palm. An increase in air temperature has been noted to shorten the development times of insects. It is speculated that population of insect pests of oil palm will increase with climate change due to the increase in temperature. Studies have shown that long dry periods provide conducive environments for outbreaks of bagworm infestations. It is likely that the long drought periods due to climate change will cause more bagworm infestation outbreaks. With an increased population and longer infestation outbreaks, heavier damage on the oil palms and higher crop loss may be expected. Unproven modelling studies have projected that *Ganoderma* disease will become more rampant with climate change.

In conclusion, this review shows that climate change in the form of global warming is expected to be a feature in Malaysia. Based on the country's climate scenario up to 2050 provided by MESTECC, oil palm cultivation can still be carried out successfully in the country. However, the changing climate will present increased risks to oil palm cultivation, the degree of risks depending on the severity of climate change, location and other local environmental factors .

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