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THE IMPACT OF PREDICTED CLIMATE CHANGE IN MALAYSIA ON OIL PALM YIELD

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INTRODUCTION

By 2050, Malaysia is expected to be warmer by 1.5 ^{0}C, experienced more annual rainfall (by 5 to 30%), and have an increased atmospheric concentration of carbon dioxide of 550 ppmv and ground level ozone concentration of 30 ppbv. Consequently, the purpose of this study was to simulate the effects of the predicted climate change in Malaysia on the yield of oil palm.

MODEL DEVELOPMENT

A semi-mechanistic oil palm model was developed. The model has seven core components. The first component is the simulation of hourly weather properties based on daily weather data. The second component is the interception of solar radiation that is based on a modified form of Beer's law to account for discontinuous canopies, which occurs when the oil palm canopies have not yet closed during the early growth period. The third component is the mechanistic photosynthesis model by Collatz *et al.* (1991) which describes that photosynthesis is either limited to Rubisco, light or sink. Leaf photosynthesis is then scaled up to canopy photosynthesis according to the method by Norman (1992). The fourth component is the estimation of the effects of ground level ozone on oil palm photosynthesis. The method by van Oijen et al. (2004) was adapted. Ozone potentially damages the pinnae and it incurs the cost of some assimilates to detoxify and repair the O_3 damages. The fifth component is the partitioning of the assimilate from photosynthesis for maintenance and growth respiration. The method by van Kraalingen *et al.* (1989) was adapted. The trunk height growth was based on an empirical relationship established from measured data from previous works. The growth of the oil palm canopy (width and height) was also based on measured data. One major deviation from van Kraalingen et al.'s model is this study's model accounts for the factor of water stress on oil palm growth and yield, where reduction in gross photosynthesis was directly in proportion to the degree of water stress. The sixth core component is the modelling of the water balance in the oil palm environment based on the Shuttleworth-Wallace (Shuttleworth and Wallace, 1985) equation. It allows for the interaction of heat fluxes between the tree and soil. The water balance for two soil depths (0-20 mm and 20 mm until rooting depth) were also modelled to determine the critical water amount based on a C3 plant. Thus, the oil palm growth and yield would decrease in proportion to the critical water level. The seventh component is the modelling the soil water content in the soil based on Darcy's law.

RESULTS AND DISCUSSION

Model simulations revealed that the predicted oil palm yield would be reduced by between 0.8 to 31.3% (equivalent to 0.2 to 6 t ha^{-1} yield reduction) (Table 1). However, if the ground level O_3 pollution can be kept below 30 ppbv, oil palm yield would instead increase by between 2 to 42% (equivalent to an increase by 0.4 to 8 t $^{ha\ 1}$). Simulations confirmed that oil palm yield would increase with increasing CO_2 concentration and total annual rainfall. In contrast, oil palm yield would reduce with higher air temperature and ground level O_3 concentration. To prevent yield reduction due to the increasing warmth and O_3 concentration, CO_2 concentration must increase to a certain threshold or "critical point" below which oil palm yield will decline. It was shown that, all properties being equal, oil palm yield reduction would be prevented if the critical CO_2 level increases by at least: a) 28 ppmv for every 1 °C increase in temperature, and b) 40 ppmv for every 30 ppbv increase in ground level O_3 concentration. The critical increase in air temperature was also calculated to be 0.6 °C (at 380 ppmv of CO_2 and 0 ppbv of O_3). This means that any temperature increases greater than 0.6 °C will reduce yield. At 380 ppmv CO_2 and 0 °C increase in air temperature, the critical level for O3 concentration was 12 ppbv after which further increases in O_3 concentration would reduce oil palm yield. Finally, the importance of CO_2, O_3, air temperature and rainfall on oil palm yield was found to be in decreasing order of: $CO_2 > O_3 >$ air temperature > rain.

Table 1. Percentage change in oil palm yield due to climate change

		Annual rainfall change											
Temp.		-770 mm (30% less)				0 mm (no change)				+770 mm (30% more)			
change	O_3	CO_2 (ppmv)											
(°C)	(ppbv)	380	420	480	550	380	420	480	550	380	420	480	550
0	0	-0.1	22.2	54.2	88.1	*(20)	22.8	54.8	88.2	4.1	28.2	61.6	96.6
	30	-21.4	0.4	29.0	60.2	-20.6	0.0	29.5	60.9	-17.4	4.1	35.2	67.7
	60	-36.9	-18.7	8.8	38.7	-36.9	-18.1	9.2	38.7	-33.9	-14.8	13.7	44.5
	120	-62.1	-48.1	-26.7	-1.6	-61.1	-47.7	-26.5	-1.4	-59.7	-45.8	-23.3	2.3
+1	0	-17.1	4.6	34.3	66.1	-13.6	7.9	37.1	68.2	-11.1	11.3	42.1	74.3
	30	-35.4	-16.0	12.1	41.5	-32.1	-12.9	14.6	43.8	-30.3	-10.3	18.7	48.7
	60	-49.0	-32.4	-6.7	21.5	-45.8	-29.3	-3.6	23.8	-44.8	-27.4	-0.8	28.2
	120	-69.8	-58.0	-38.9	-15.1	-67.3	-55.1	-35.8	-12.7	-66.6	-54.0	-34.2	-10.0
+2	0	-29.2	-9.1	19.5	50.2	-26.2	-6.1	21.9	51.9	-17.8	1.9	31.2	62.6
	30	-45.8	-27.9	-1.6	26.8	-42.7	-24.9	1.3	28.9	-34.2	-16.7	9.1	38.0
	60	-58.4	-42.9	-18.7	8.2	-55.2	-39.7	-15.8	10.7	-46.4	-31.3	-8.0	18.5
	120	-76.3	-65.8	-48.6	-26.0	-74.5	-63.4	-45.2	-23.1	-68.5	-55.6	-36.7	-15.3

Note: Value marked * indicates the oil palm yield at 20 t ha-1 which is the simulated mean anual yield for current weather conditions and for CO_2 and O_3 concentrations at 380 ppmv and 0 ppbv, respectively. All other values are the percentage change in oil palm yield due to climate change, where shaded values denote reduced yields.

Further study is ongoing to include the effects of soil type (i.e., different textures) and diferent rainfall distribution patterns on oil palm yield.

CONCLUSION

Model simulations revealed that the predicted oil palm yield would be reduced by between 0.8 to 31.3% (equivalent to 0.2 to 6 t $^{ha-1}$ yield reduction). Simulations confirmed that oil palm yield would increase with increasing CO_2 concentration and total annual rainfall. In contrast, oil palm yield would reduce with higher air temperature and ground level O_3 concentration. Finally, the importance of CO_2, O_3, air temperature and rainfall on oil palm yield was found to be in decreasing order of: $CO_2 > O_3 >$ air temperature > rain.

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