Effect of climate change on oil palm yield in Malaysia: Some simulations

Projections by MOSTE (now called MOSTI or the Ministry of Science, Technology and Innovation) in 2000 established that oil palm was relatively robust to climate change compared to rice, rubber, and cocoa. Oil palm yield was rather insensitive to increases to air temperature by up to 1.4 degrees Celsius.

Year	2020			2040				2060			
CO_2 (ppm)	400	400	400	CO_2 (ppm)	600	600	600	CO_2 (ppm)	800	800	800
Temp. increase °C	0.3	0.85	1.4	Temp. increase °C	0.4	1.4	2.4	Temp. increase °C	0.6	2	3.4
Rainfall Change (%)				Rainfall Change (%)				Rainfall Change(%)			
14%	21.5	21.5	22.0	23%	24.0	24.0	24.0	32%	26.0	26.0	26.0
7%	23.0	23.0	23.25	11%	25.0	25.0	25.0	15%	27.0	27.0	26.0
0.40%	22.5	22.5	22.75	0.70%	24.5	24.5	24.5	1%	26.0	26.0	25.0
0	22.0	22.0	22.0	0%	24.0	24.0	24.0	0%	26.0	26.0	26.0
−0.40%	22.0	22.0	22.0	−0.70%	23.5	23.5	23.0	−1%	24.0	24.0	22.0
−7%	17.6	17.6	17.0	−11%	19.2	19.2	18.7	−15%	18.0	18.0	15.6
−14%	15.4	15.4	15.4	−23%	15.6	15.6	14.9	−32%	14.3	14.3	13.0

Note: Yield expressed in tonnes/ha/yr

MOSTE's prediction of climate change effect on oil palm yield. They predicted that oil palm was relatively robust to climate change as compared to other crops like rubber, rice, and cocoa (source: MOSTE, 2000).

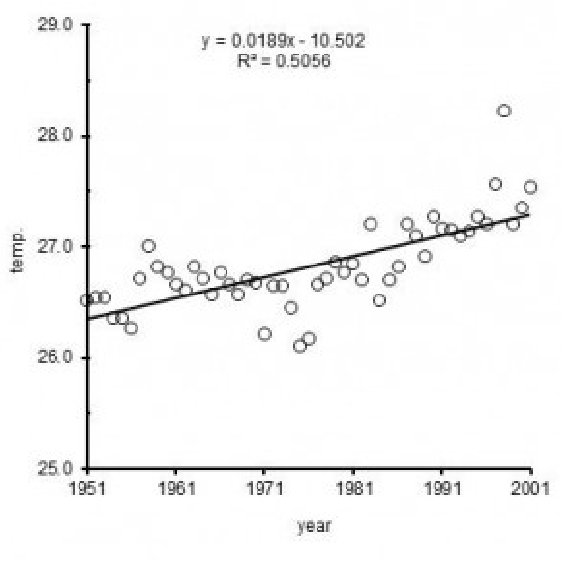
Oil palm was instead sensitive to drier weather. Oil palm yield declined by about 1% for every 1% reduction in the amount of rain. Higher amounts of rain led to increases in oil palm yield unless the increased rainfall led to flooding.

Expectedly, increases in ambient air CO_2 concentration led to increases in oil palm yield by about 10% for every 200 ppmv (parts per million by volume) increase in CO_2 concentration.

Unfortunately, the MOSTE's report contained very little information on how they had made these predictions or what mathematical model they had used to predict Malaysia's expected climate change on oil palm yield.

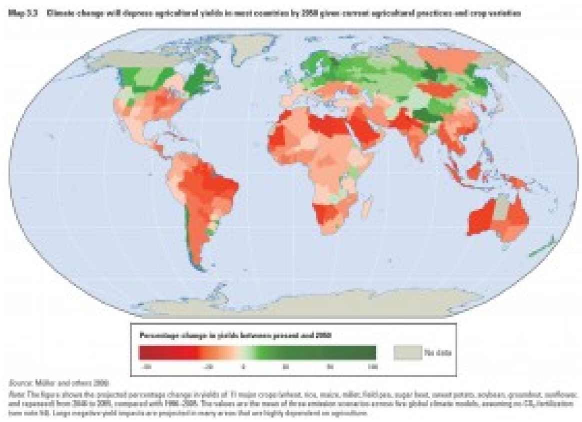
Here in this article, I present some ***tentative*** predictions based on the latest knowledge on oil palm physiology. I like to stress emphatically that this article contains *tentative predictions*. I am planning to follow the proper route to publish my research findings in a peer-reviewed journal once I have completed my research. I am putting these results (albeit tentative) here because there is much interest to understand how climate change would affect oil palm yield.

Malaysia experiences hot and wet tropical climate, with a typical daily air temperature of between 20 to 30 degrees Celsius. Overall, Malaysia sees an increase in air temperature by 0.18 degrees Celsius per decade (every ten years). Increased air temperature in an already hot country like Malaysia would be detrimental to crop yields. Without CO_2 fertilization (that is, if ambient air CO_2 did not increase), crop yields in Malaysia are expected to decline by 10 to 20% by 2050, as estimated by the World Bank in 2010.



Malaysia sees a 0.18 degrees Celsius increase in mean annual air temperature per decade (source:

MOSTE, 2000)

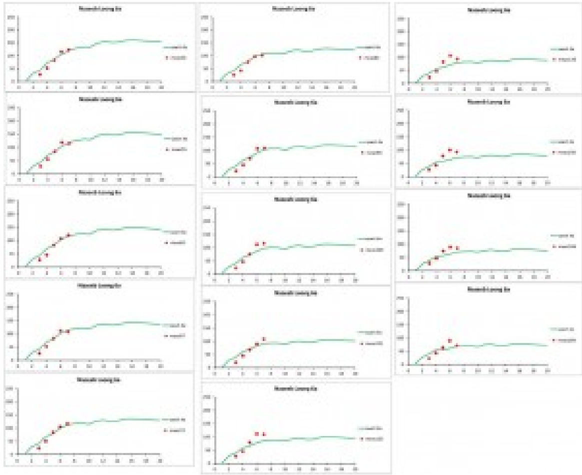


Without CO_2 fertilization, crops yields in warm regions of the world are expected to decline (source: World Bank, 2010).

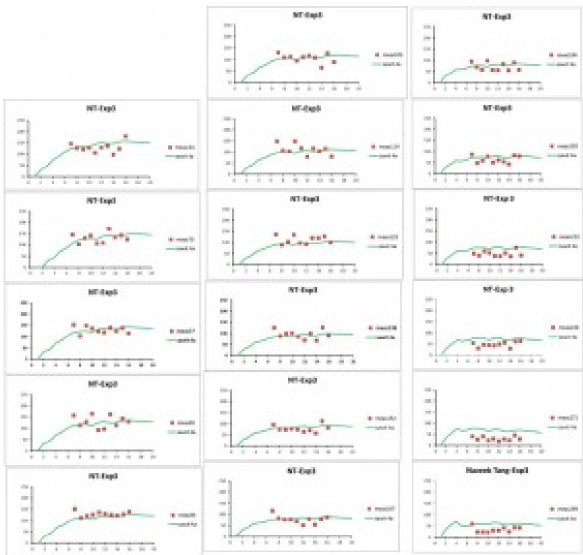
Malaysia sees a typical annual rainfall of between 2000 to 3000 mm. Latest estimates indicate that Malaysia would experience drier weather in some regions (such as Selangor and Johor) but wetter weather in others (such as East coast of Peninsular Malaysia). Overall, Malaysia is expected to see changes in annual rainfall by about -0.7 to 23% by 2040.

Limited field research in Malaysia have showed that oil palm yields could increase by as little as 5% to as much as over 100% if oil palm's daily water demand is met by irrigation. These research highlighted one important point: that is, current oil palm yields in Malaysia are depressed due to lack of water. Consequently, higher rainfalls in Malaysia would be good news as they would bring increases in oil palms yields, provided the heavier rains do not cause flooding or water ponding.

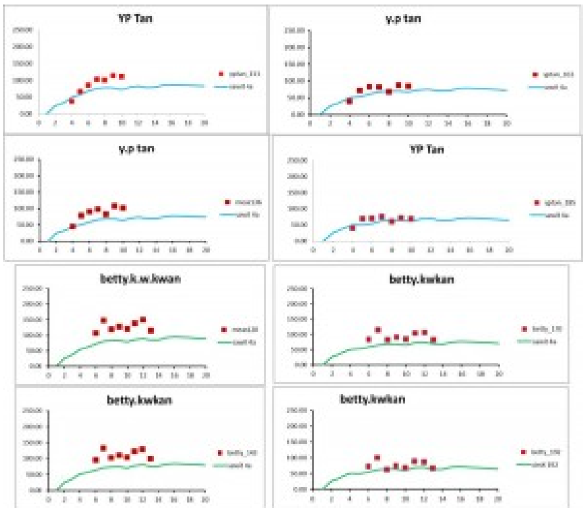
To determine the effect of climate change in Malaysia on oil palm yield, I developed a mathematical model to describe the growth of oil palm. This model is a culmination of several years with the feedback and help from various researchers. I present four sets of validation tests below to determine how accurately the model estimated the oil palm yields.



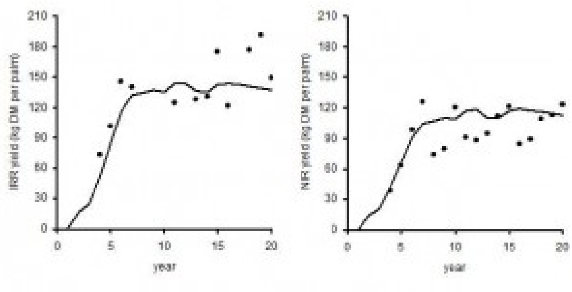
Set 1 of 4. Overall, fairly good agreement between model estimations (line) and measured (dots) oil palm yields (in kg dry matter per palm) for various planting densities.



Set 2 of 4. Overall, fairly good agreement between model estimations (line) and measured (dots) oil palm yields (in kg dry matter per palm) for various planting densities.



Set 3 of 4. Overall, fairly good agreement between model estimations (line) and measured (dots) oil palm yields (in kg dry matter per palm) for various planting densities.



Set 4 of 4. Overall, fairly good agreement between model estimations (line) and measured (dots) oil palm yields (in kg dry matter per palm) for 148 palms per hectare planting density. Chart on the left denotes irrigated trial and the chart on the right is non-irrigated trial.

Seeing the overall satisfactory agreement between the model estimations and measured oil palm yields, the model was subsequently used to predict increases in CO2 concentration, air temperature, wind speed, and sunshine hour on oil palm yield. Note that the baseline for comparisons are the following: CO_2 concentration = 390 ppmv; mean daily minimum and maximum air temperature = 24 and 32 degrees Celsius, respectively; mean daily wind speed = 1.5 meters per second; and mean daily sunshine hours = 6 hours. Planting density was set at 148 palms per hectare.

The following table shows the oil palm yields at various scenarios. The orange shade indicates the baseline oil yield, and the grey shade indicates decline in oil palm yield compared to the baseline yield. Although the table may look complicated with numerous values, the trend is actually simple that with increasing CO_2 concentration, wind speed, and sunshine hours, the oil palm yield would increase. However, increases in air temperature would decrease oil palm yields.

		+0 °C			+1 °C			+2 °C		
CO2 (ppmv)	Sunshine hours	1.50 m/s wind	2.25 m/s wind	3.00 m/s wind	1.50 m/s wind	2.25 m/s wind	3.00 m/s wind	1.50 m/s wind	2.25 m/s wind	3.00 m/s wind
390	1	80	99	109	58	78	89	36	57	68
	2	94	116	128	70	93	105	46	69	82
	3	103	129	142	78	104	118	52	79	93
	4	106	135	150	80	109	125	55	82	99
	5	104	135	152	77	109	126	56	82	100
	6	99	132	150	74	106	124	54	79	98
	7	89	125	143	69	99	118	50	75	92
	8	79	112	132	60	87	107	43	67	82
450	1	103	123	133	81	101	112	57	79	90
	2	119	142	154	94	118	131	68	93	107
	3	130	158	170	103	130	145	75	104	119
	4	135	165	181	107	138	154	78	110	127
	5	134	167	185	105	139	158	77	110	129
	6	129	165	184	100	137	156	75	107	127
	7	120	158	178	93	130	151	71	101	122
	8	105	148	167	83	119	141	63	91	112
550	1	135	154	164	111	132	143	86	109	121
	2	153	178	188	127	152	165	100	126	140
	3	167	193	207	138	167	182	108	139	155
	4	174	205	220	144	177	193	112	146	164
	5	177	212	229	145	182	201	112	150	170
	6	172	211	231	140	180	202	107	147	170
	7	163	205	227	131	174	197	101	141	165
	8	149	195	218	118	163	188	93	131	156

My model's prediction of climate change on oil palm yield. The base value is denoted by the orange shade. The grey shades denote decline in oil palm yield as compared to the base value.

I summarized the results from the above table into a multiple linear regression. The linear regression indicates that oil palm yield is sensitive to the four factors in the following order: CO_2 > air temperature > wind speed > sunshine hours.

On average, for every:

- 100 ppmv increase in CO_2, oil palm yield *increases* by 40%,
- 1 degree Celsius increase in air temperature, oil palm yield *declines* by 27%,
- 1 meter per second increase in wind speed, oil palm *increases* by 32%,

and

- 1 hour increase in sunshine hour, oil palm *increases* by 3%.

These results indicate that oil palm yield is, as expected, sensitive to CO2 concentration and air temperature. The yield benefits of the increase CO2 is counterbalanced by the increase in air temperature.

Less expectedly, however, wind speed plays a big role in affecting oil palm yields. Stomatal conductance increases with increasing wind speeds, which in turn increases photosynthesis; thus, increasing the growth rate and yield of oil palm. The role of wind speed on oil palm is underestimated and under appreciated. In Malaysia, coastal soils often give higher oil palm yields as compared to that on inland soils. This is often attributed to higher soil fertility for coastal soils than for inland soils. But another possible reason could be that coastal soils experience higher wind speeds than those inland soils.

When air temperature increases, this would increase water evaporation, which would lead to more cloud formation and rain. Greater amount of clouds, however, would reduce the amount of solar radiation reaching the oil palm fields. So, would oil palm yields subsequently fall? My results however indicate that a change in sunshine hour has little impact on oil palm yields.

Malaysia already receives high amounts of solar radiation (10 to 20 MJ per square meter per day). Consequently, further increases in solar irradiance may not lead to further increases in photosynthesis because photosynthesis could be instead limited by the Rubisco enzyme capacity.

Many people had expected that Malaysia’s past haze experiences would cause a decline in oil palm yield because of the lower solar irradiance. Dr Ian Henson, then from Malaysian Palm Oil Board (MPOB), simulated that the haze could cause higher, not lower, oil palm yields. This is because of the lower air temperature (brought by the haze blocking the sunlight) would increase oil palm stomatal conductivity. In turn, this increases the photosynthesis rate, which would increase oil palm yield despite lower solar irradiance.

There are some important caveats on the results of model simulations presented here. The model makes a major assumption that climate change would not affect the oil palm physiology. In open-field experiments conducted for annual crops showed that crops do adapt to a changing climate. For instance, C3 plants became “desensitized” to increases in CO_2 concentration. Moreover, although increases in CO_2 concentration brought increased in crop yields, the quality of crop yields declined. Rice, for instance, saw a decline in Fe, Zn, and Ca nutrients despite increase in rice yields due to increase in CO_2 concentration to 700 ppmv.

Model predictions on climate change effect on oil palm yield make an important assumption that oil palm physiology remains the same in a changing climate (photo from co2tropicaltrees.blogspot.com).

To conclude, I like to remind the model simulations presented here are only ***tentative***. My oil palm model is still work in progress. I am still unhappy on some aspects on the model. I am currently modifying it, which would require further validation against measured oil palm data. Once completed, my work would be submitted to journals for publication.

Source

1. MOSTE. 2000. Malaysia. Initial National Communication. Report submitted to the United Nations Framework Convention on Climate Change. Ministry of Science, Technology and Innovation, Putrajaya.
2. World Bank. 2010. World Development Report 2010: Development and Climate Change. The World Bank, Washington.