Potential Impacts of Climate Change on Oil Palm Cultivation

A science-for-policy paper by the SEnSOR programme

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Cover photo: oil palm plantation and mill in Sabah, Malaysia. Photo credit: Robin M. Hayward

Key messages

1. **Warmer temperatures** during the 21st century will **enable oil palm to grow in new locations,** although the **total area suitable for growing oil palm will decrease.**

2. **Increased droughts and risk of flooding will reduce oil palm yields** in the future, but these losses may be **partially mitigated** by higher temperatures and carbon dioxide **levels**, which **can increase plant productivity**.

3. To continue planting without further loss of forests and natural habitats, we need **better knowledge of suitable locations** for growing oil palm in the future.

4. **Adaptive management** of oil palm should help **reduce loss of yield**, such as by preparing for **irrigation**, developing and planting **oil palm varieties** which tolerate different climates, preparing for changes to **pests and diseases**, and supporting **pollinators**.

5. We recommend that the **RSPO develops guidance for adaptive management** for climate resilience for growers.

6. We recommend that the RSPO P&Cs and the New Planting Procedure include an **assessment of the potential impacts** of climate change at a planting site, to ensure the **long-term viability** of new plantations.

What is climate change?

Global **weather patterns and sea levels are changing because of increasing temperatures** caused by **human activities releasing greenhouse gases** into the atmosphere (Bindoff *et al.* 2013; Cubasch *et al.* 2013; IPCC 2013). **Carbon dioxide has been the main cause of global warming to date,** mainly released into the atmosphere from use of fossil fuels and from land-use change such as deforestation, although other greenhouse gases such as **methane** are also significant contributors (IPCC 2013). **Greenhouse gas emissions and temperatures will continue to increase throughout the 21st century.** This will cause a **higher frequency and intensity** of **extreme weather events** such as heatwaves, drought, and sudden heavy rainfall. Sea levels are also continually rising with temperature increase.

The **RSPO P&Cs include a strong focus on reducing greenhouse gas emissions** from the oil palm industry, which are intended to limit the contribution of the industry to climate change. Under P&Cs 5.6 and 8.1, oil palm growers and millers are required to monitor and report greenhouse gas emissions, and to implement plans to reduce these. Under P&C 7.8, new plantations must be designed to minimize net greenhouse gas emissions, both from land-use change and from milling operations (RSPO 2013). For example, companies must avoid planting on land with high carbon stocks, including areas of intact forest or peat soil and use efficient boilers in the mills (RSPO 2013). Evidence from Indonesia shows that **certification is having some positive impact on emissions reduction** in the industry, as RSPO-certified plantations have **reduced rates of deforestation and incidence of fires**; however the extent of the impact is unclear, as these rates are not reduced to zero (Carlson *et al.* 2017).

How will climate change affect where oil palm is grown?

What is a suitable climate for growing oil palm?

Oil palm requires high temperature, rainfall and sunlight levels (table 1). Oil palm yield is **limited by the length of annual dry season**, so areas with consistently high rainfall throughout the year have particularly high yields, such as in parts of Southeast Asia (see fig. 1; Munévar 2003; Arshad *et al.* 2012; Corley & Tinker 2015; Pirker & Mosnier 2015; Pirker *et al.* 2016). Although much of the tropics is climatically suitable for oil palm, there is relatively **low availability of land** for planting globally, given other land uses and restrictions such as no planting on high carbon stock areas (Pirker *et al.* 2016).

Table 1. Key components of climate which determine the suitability of a location for growing oil palm.

Component of climate	Optimal range for growing oil palm	Range of extreme values which oil palm tolerates	References
Temperature	Mean annual temperature of **24-33°C**	15-38°C Cold tolerant varieties may tolerate 12°C	Bastos *et al.* 2001; Mantel *et al.* 2007; Arshad *et al.* 2012; FAO Ecocrop 2013; Corley & Tinker 2015; Paterson *et al.* 2015; Pirker & Mosnier 2015; Pirker *et al.* 2016
Rainfall (mean annual rainfall)	**2000-2500mm**	1250-6000mm	Munévar 2003; Arshad *et al.* 2012; Corley & Tinker 2015
Seasonality of rainfall	**Minimal**: no months with <100mm rainfall	Up to 6 months with <100mm rainfall; tolerates temporary flooding	Corley & Tinker 2015
Sunlight (solar radiation)	**15-17MJm^{-2}day^{-1}**	7-21MJm^{-2}day^{-1}	Corley & Tinker 2015; Rhebergen *et al.* 2016

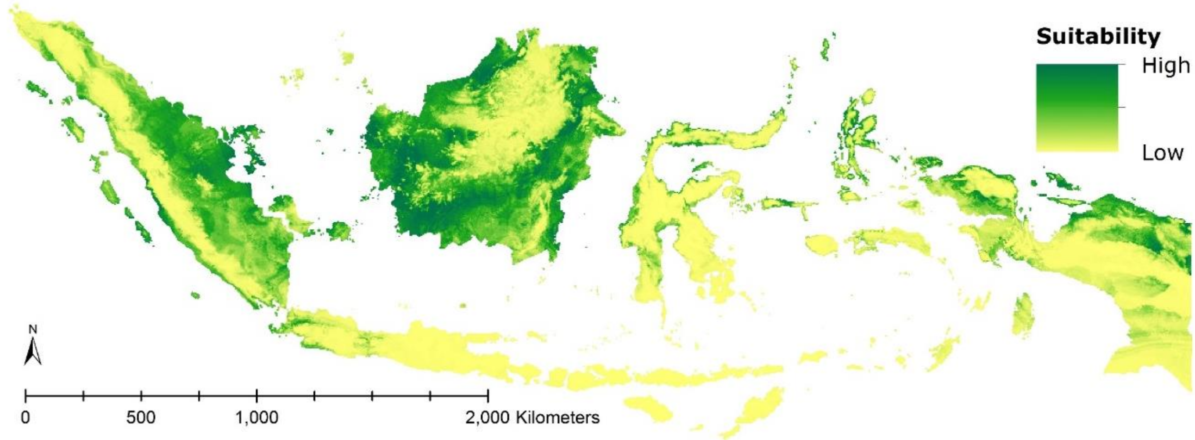

Figure 1. Modelled distribution of areas suitable for growing oil palm in Indonesia and Sarawak at the current climate (see appendix for methods)**.** See Pirker *et al.* (2016) for a global assessment of areas currently suitable for planting oil palm without deforestation.

Where will oil palm grow in the future?

Climate change will directly affect where oil palm is grown, because the **locations of areas suitable for growing oil palm will shift over the 21st century** (Corley & Tinker 2015).

Temperatures will become too high, and drought risk will increase, so **by 2100, there will likely be around three-quarters less land which is highly suitable for growing oil palm** (Li *et al.* 2009; Paterson *et al.* 2015, 2017). A particularly severe loss of suitable land is predicted for Thailand, Columbia and Nigeria, which are all significant oil-palm growing nations; and parts of Indonesia and Malaysia will also become less suitable.

Currently, areas at high elevation and latitude (far from the Equator) are too cool for growing oil palm, but as temperatures become warmer, these may become newly suitable, (Corley & Tinker 2015; Paterson *et al.* 2015, 2017). However, **this will not be sufficient to compensate for the total loss of suitable areas for growing oil palm**. Warmer temperatures, and in some instances wetter climates, will improve the suitability of areas such as northern Argentina, parts of southern Brazil, South Africa, Madagascar, and highland areas of Malaysia and Indonesia throughout the 21st century (Paterson *et al.* 2015, 2017).

How will climate change affect oil palm yield?

Overview

Climate change will have multiple effects on oil palm yield, depending on the specific climatic conditions at a location, and changes to pests and diseases of oil palm (table 2). However, we do not know how the combination of these effects will affect oil palm yield overall, and whether the positive effects on oil palm yield will compensate for the negative effects.

Table 2. How factors which determine oil palm yield will change over the 21st century, and how this will affect oil palm yield.

Factor which affects oil palm yield	Expected changes over the 21st century	Impacts on oil palm yield
Rainfall: total per year 	Depends on location. May increase or decrease.	**Gain in yield** likely if total rainfall increases (provided this does not cause prolonged flooding). **Loss of yield** likely if total rainfall decreases.
Rainfall: seasonality 	Rainfall will become less regular: dry periods will become more intense and flooding will occur more regularly	**Severe loss of yield**
Temperature 	Increase	**Loss of yield** likely (mainly because soils become drier).
Carbon dioxide 	Increase	**Gain in yield**
Sea levels 	Increase	**Severe loss of yield** in coastal plantations
Pests and diseases 	Various changes	Uncertain
Pollination 	Various changes	Uncertain

Impacts of changes in rainfall

The greatest risk for loss of oil palm yield is an increase in dry periods, because of changes in rainfall, but we do not have high confidence in predictions of future rainfall at specific locations.

The most important factor determining oil palm yield is the availability of water in the soil, which largely depends on rainfall, but is also affected by temperature and other factors such as soil type. When there is less rainfall, there is also **greater risk of fire,** as seen during recent El Niño events in Indonesia, which is a hazard for workers, in terms of air quality, and causes loss of yield (Bakoumé *et al.* 2011; Noojipady *et al.* 2017).

Although there is **low confidence in predictions of future rainfall for specific locations**, there is more confidence in changes at a larger scale. The risks of **drought and flooding will increase** across the tropics throughout the 21st century given that the effects of ENSO (El Niño Southern Oscillation, which causes El Niño and La Niña events) will become more intense (Christensen *et al.* 2013). Drought frequency and intensity will increase in parts of West Africa over the coming decades, and will become more likely in parts of Southeast Asia, where annual dry periods are predicted to become more intense (Li *et al.* 2009; Chotamonsak *et al.* 2011). Low-lying areas are also at risk of yield loss due to flooding (Wen & Sidik 2000).

Figure 2. Oil palm worker harvesting fresh fruit bunches. Photo credit: Ahmad Bin Jelling.

Impacts of increasing temperature

Warmer temperatures will also cause dry periods to increase, which will cause loss of oil palm yield.

As temperatures become warmer, soil water evaporates more quickly, so the impacts of dry periods become more intense. The impacts of higher temperatures alone are likely to be less severe, but projections for Southeast Asia in 2100 suggest that temperatures will become too high for oil palm (Corley & Tinker 2015; Paterson *et al.* 2015). A small rise in temperature may improve oil palm yield, as seen on the west coast of Sabah (Wen & Sidik 2011).

Impacts of increasing carbon dioxide levels

Higher levels of carbon dioxide in the atmosphere will improve oil palm yield, because rates of photosynthesis increase.

Yields could improve by up to 75% in 2100 due to higher carbon dioxide levels, although this depends on the increase in temperature (Corley & Tinker 2015). It is unsure whether increasing carbon dioxide levels will offset the losses in oil palm yield caused by climate change, because the combined effects of these are not well understood (Long *et al.* 2006).

Impacts of rising sea levels

There is a serious risk of flooding of oil palm estates in coastal areas due to sea level rise (Siwar et al. 2013; Corley & Tinker 2015).

In Malaysia, up to 100,000ha of coastal plantations could be flooded in the future (Siwar *et al.* 2013). Coastal estates can be managed to reduce flood risk, but the costs of this will increase in tandem with the rise in sea levels. Mangrove forests provide an effective defense against coastal flooding, so the oil palm industry can reduce climate change impacts by avoiding clearing these for planting (Temmerman *et al.* 2013).

Impacts of changes in pests and diseases

Climate change will affect pests and diseases of oil palm (such as insect pests and bacterial and fungal diseases), although the effects of this on oil palm yield are unclear and will vary by location (Paterson et al. 2013, 2015).

Differing environmental conditions may be less suitable for pests and diseases of oil palm, which would allow yield to improve. However, there is particular uncertainty regarding pests and diseases in possible new locations for oil palm. When conditions are sub-optimal for oil palm, such as when temperatures are high or there is limited water availability, palms may be less able to resist pests and diseases, causing yield loss.

Impacts of changes in pollination

Climate change may have negative impacts on the pollination of oil palm, resulting in yield loss.

Oil palm in Southeast Asia is primarily pollinated by a single species of weevil, *Elaeidobius kamerunicus*. The pollination activity of this species changes with climate, so it is possible that the rate of pollination of oil palm in Southeast Asia will decrease under climate change (Jackson *et al.* 2010). Additionally, climate change could put *E. kamerunicus* and other pollinators at greater risk of disease (in a similar way that oil palm may have greater risk of disease). Just a small number of individuals of *E. kamerunicus* were introduced to Southeast Asia from West Africa, so all individuals in Southeast Asia are genetically similar (Jackson *et al.* 2010). There is a risk that a disease which infects *E. kamerunicus* in Southeast Asia could quickly and severely reduce the population, causing a sudden drop in yield (Jackson *et al.* 2010).

Where should oil palm be planted?

The changes to locations where oil palm can be grown, and the potential yield losses in current plantations, will **enable oil palm to expand into new areas over the 21st century. This will increase the risk of deforestation** of suitable areas for planting among **non-RSPO members**. In particular, areas at **high elevation** will become suitable for growing oil palm, but in many tropical regions, the majority of large areas of forest are also at high elevation (Proctor *et al.* 2011). These large areas of forest at high elevation are particularly important for tropical biodiversity under climate change, because they are cooler than the lowlands, so species can shift to these locations to avoid high temperatures (Proctor *et al.* 2011; Struebig *et al.* 2015a; Scriven *et al.* 2015).

For new oil palm plantations to be viable in the long-term, **they should be located where there is a low risk of negative impacts from climate change, and ideally where conditions for oil palm may improve.** There is currently **limited knowledge** of where such areas coincide with low forest cover, to enable planting without deforestation. The most suitable new areas are likely to be in South America and Africa, such as southern Brazil and South Africa, because in Southeast Asia, highland areas will become more suitable, but these are generally forested (Hansen *et al.* 2013; Paterson *et al.* 2017).

Figure 3. Landscape of oil palm and forest in Sabah, Malaysia. Photo credit: Robin M. Hayward.

What can the RSPO and its members do?

Adaptive management of oil palm for resilience to climate change

Oil palm growers should consider becoming more **flexible and adaptive in their management** in order to maintain oil palm production as the climate changes. This could include measures such as the installation of **irrigation systems** to supplement low rainfall.

At a given plantation, **oil palm varieties should be selected that tolerate the more extreme climatic conditions**. Oil palm breeding programmes have been initiated to achieve this, but efforts should to be stepped up to meet needs and to ensure that **all oil palm growers, including smallholders, have access to new varieties** (Rival 2007; Barcelos *et al.* 2015).

It is important to **maintain the genetic diversity of oil palm, its pollinators, and cover crops** to ensure that some of the oil palm crop and pollinator population will persist as the climate changes. Genetic diversity is particularly important to **safeguard against yield loss from pests and diseases**, because climate change may cause unexpected outbreaks, and the pests and diseases in new locations for plantations will be unknown. In Southeast Asia, it would be prudent to increase the diversity of pollinators (Jackson *et al.* 2010).

Oil palm landscapes should also be managed to **reduce negative impacts of climate change on biodiversity**, if High Conservation Value areas are to maintain biodiversity successfully. **Forested areas should be connected** (or reconnected) across **elevation gradients** in order that species are able to shift ranges as temperatures warm (Scriven *et al.* 2015).

Incorporating climate change resilience into RSPO policy

The RSPO P&Cs address climate change mitigation by reducing greenhouse gas emissions from oil palm, but **do not address potential impacts of climate change on the industry** (RSPO 2013). In line with other policies on long-term planning for sustainable oil palm production, **we therefore recommend that RSPO P&Cs incorporate adaptive management strategies for climate change.**

Principle 3 "Commitment to long-term economic and financial viability" currently requires various projections, including for yield of FFB and cost of production for a minimum of three years. As climate change is almost certain to strongly impact both yield and production cost, long-term management plans for climate change could be incorporated into the requirements here. Principle 4 "Use of Appropriate Best Practices by Growers and Millers" should also refer to adaptive management.

Principle 7 "Responsible Development of New Plantings" should include avoidance of planting on sites which are likely to be severely negatively impacted by climate change.

Addressing knowledge gaps

There is currently a **limited understanding of how different components of climate change will combine to affect oil palm yield**. Furthermore, recommendations for sustainable land-use planning for oil palm (e.g. expanding without deforestation) do not generally include the impacts of climate change on oil palm cultivation.

We will undertake future work to address this, by **investigating the effects of climate on oil palm yield in Southeast Asia, how this will change in the future, and implications for land-use change.** We will test the importance of different components of climate (both individually and combined) for oil palm yield, and we will use this understanding to make yield projections for the future. We will highlight areas likely to become suitable for cultivation, focusing on areas at risk of deforestation, and non-forest areas into which oil palm may expand sustainably. By identifying non-forest areas which are likely to have high yields throughout the 21st century, we will provide the RSPO with information on locations suitable for sustainable planting considering climate change, directly relevant to Principle 3 "Commitment to long-term economic and financial viability" and Principle 7 "Responsible Development of New Plantings" (RSPO 2013).

Additionally, it is currently unknown if **additional pollinator species from West Africa could be introduced to other regions** without impacting native biodiversity (e.g. whether introduced pollinators may become a pest outside oil palm plantations). We also do not know if other species native to Southeast Asia or the Americas also pollinate oil palm, and how management could support these.

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Appendix

New model of areas suitable for oil palm cultivation in Indonesia and Sarawak

As part of ongoing work investigating the effects of climate change on the oil palm industry, we are modelling how climate determines current and future locations suitable for growing oil palm. We have modelled the current suitability of Indonesia and Sarawak for oil palm, as a preliminary output (fig. 1 in main text). Our model highlights that lowland areas with consistently high year-round rainfall are highly suitable for growing oil palm, such as much of lowland Borneo. We found that coldness (minimum temperature of the coldest month) was the most important component of climate for predicting the suitability of locations for growing oil palm. This supports the current knowledge that locations suitable for growing oil palm will change as temperatures become warmer.

Details on the methods used to create the model

We used the species distribution model Maxent to simulate the suitability of Indonesia and Sarawak for growing oil palm. We used oil palm concessions locations (areas designated as plantations by law), retrieved from Global Forest Watch, as presence data, and we created an equal number of pseudoabsence points to represent locations outside the concessions areas (SADIA, Aidenvironment & Earthsight Investigations 2016; Indonesia Ministry of Forestry 2016). We used 75% of the presence data were used to fit the model and 25% to test it. We obtained climate data from WorldClim at 2.5min resolution (Hijmans *et al.* 2005). We selected five bioclimatic variables as predictors of suitability for oil palm, based on information obtained from literature, and after checking for inter-correlation. These five bioclimatic variables were temperature seasonality (coefficient of variation), minimum temperature of the coldest month, mean temperature of the warmest quarter, rainfall of the driest quarter, and rainfall of the warmest quarter.

The projected model for Southeast Asia fits the concessions data with AUROC = 0.85 (Area Under Receiver Operating Characteristic: a measure of accuracy of the model; a perfectly accurate model would have AUROC = 1). The minimum temperature of the coldest month was the most important climatic variable, with a sharp peak of oil palm occurrence at approximately 22°C. Temperature seasonality was next-most important, with greater occurrence at lower seasonality.

Figure 4. Industrial oil palm concessions (locations designated for planting oil palm) in Indonesia (blue) and Sarawak, Malaysia (orange). Data were obtained from Global Forest Watch (SADIA, Aidenvironment & Earthsight Investigations 2016; Indonesia Ministry of Forestry 2016).