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# Oil palm in the face of climate change: A review of recommendations

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**Abstract.** Climate change imposes serious challenges in oil palm production and the current pace of adaptation and mitigation cannot continue to support oil palm production. We reviewed and analysed literature that reports sustainable recommendations, adaptation and mitigation measures to deal with impacts of climate change. Literature spanning the period 2000-2020 were systematically reviewed and several consistent recommendations emerged which require time frame and actionable plan for sustainability. The review categorized the identified recommendations into groups; fertilizer, policy, soil management, sustainability, water management, research and development, best development practices and agroecological practices. Sustainable implementation of adaptation requires collaboration from diverse disciplines to come together and work toward defined objective(s) through certain principles that guide adaptation; these principles must be consistent, operational and more specific, must be practical and achievable recommendation for inclusion into policies and must be embrace by all and sundry for sustainable development.

## 1. Introduction

The impacts of climate change on oil palm manifested in the shift and variability of rainfall intensity and uncertainties of weather pattern brought about drought and extreme precipitation leading to flooding and destroying oil palm plantation along the coastal regions. Sea level rise has a profound negative impact on oil palm production, according to [1] stated that in any case if the plantation area decreased by 1% the oil palm yield decline by 0.99%. If the area under oil palm production decreased by 2%, 4%, and 8% due to sea level rise of 0.5, 1.2 m, oil palm production is anticipated to decline by 1.98%, 3.96% and 7.92% in Malaysia respectively [2] [3]. However, it is currently estimated that 208,000 or 12% of the land under oil palm cultivation would become marginal and hardly support oil palm plantation when the current trends of warming continues any rise in temperature by “1°C (3.57%), 2°C (7.15%), 3°C (10.72%) and 4°C (14.29%), then oil palm production can decrease in Malaysia by 10.17%, 20.38%, 30.55%, and 40.73%, respectively” [1] [4] [5].

The other impacts of climate change on oil palm production include, increase abortion, elongated inflorescence, low productivity, rotten bunch, water stress expanded lance leaf number and upper biomass break (frond) substantially decrease oil palm productivity, decrease in male and female flower, tissue and cells dehydration, decreasing nutrients uptake, disruption in general metabolism and influences photosynthesis negatively, outbreak of pest and diseases due increase in temperature which changes the fecundity and life cycle of the pest and influences the pollination process and changes the modus operandi of the pollinators such as *Elaeidobius kamerunicus* [6] [7]. According study conducted



in Johor reported declined in FFB to 3.76 t/ha in 2006, 4.23 t/ha in 2007 and 4.34 t/ha in 2008 [8]. These led to revenue declined by RM 1139 million in 2006, RM 2156 million in 2007 and RM 2436 million in 2008 due to *Ganoderma* infestation.

Having painted the ugly picture of climate change in the oil palm sector, how can we adjust to the system? Our emphasis here focused on adaptation as an alternative means to the impacts of climate change. Adaptation simply refers to the “adjustment in human or natural systems, including structures, process and practice [9].

## **2. Materials and methods**

### *2.1. The study area*

Malaysia is geographically located in Southeast Asia (2°30' N 112° 30' E coordinates) with two segments; the peninsular Malaysia and East Malaysia or Borneo. The Peninsula Malaysia is located in the southern most section in Malay Peninsula, south of Thailand north of Singapore, and east of Indonesian Island of Sumatra. The east Malaysia comprises large parts of northern Borneo Island and shared bordered with South China Sea to the west, Brunei from the north and Indonesian Borneo to the South. Malaysia is characterized by hot and humid climate throughout the year and two seasons; the southeast monsoon associated with drier conditions and northeast monsoon accompanied by wet season

### *2.2. Methods*

In search of relevant literature, we used web of science, ISI web of knowledge, google search, google scholar and Malaysia Palm Oil Board database to search for published articles on climate change and palm oil production and management. We used search terms “climate change” in combination with search string oil palm or, palm oil, or oil palm adaptation, or oil palm mitigation, or oil palm policies, or oil palm management, or oil palm agronomic practices, or oil palm and EL-Nino and or oil palm pests and diseases. The basis for recommendation inclusion criteria such recommendations must be empirical research, review articles, case studies, conferences, seminar and workshops. Studies from theory and personal opinion were excluded. And such recommendation must be explicit and clear with specific target and actionable time plan in policy formulation and execution. And does that recommendation provide the necessary information needed in adaptation planning. Articles that do not report impacts, adaptation, mitigation and or recommendation were excluded from the document selection. We read and select 87 articles that provide explicit recommendation for the sustainable oil palm management.

For proper analysis of these recommendations we create database and categorize the adaptation into eight (8) and record every adaptation that is reported into a fit database to enable further analysis and understand the perceived best recommended adaptation priority reported in the literature.

**Table 1.** List of recommendations for climate change adaptation in oil palm sector.

Recommendations	No of Articles	References
<b>Fertilizer</b>		
Fertilizer application (i.e French system, PORIM Open system, Foster system and INFERS), nutrients balance approach, reducing or avoiding fertilizers, avoid using herbicides	19	[10] [11] [12] [13] [14][12][16] [17] [18] [19][20][21] [22] [23][24][25] [26][27] [28]
<b>Policy</b>		
Improved regional academic leadership, coordination, engaging private and public stakeholders, emphasized collaborative efforts with researchers in consumer countries, commitments to right, ownership and no exploitation of workers and local communities, adhere to national policies and certifications, respect land tenure rights, reduce GHGs emission, no development on high forests, access to finance, land use policy use policy, infrastructural development , sustainable policies, environmental regulations	21	[1][18][29][24][28][30][31] [32][33] [34][35] [36][37] [38][39][40][41] [42][43][44][45]
<b>Research and Development</b>		
Enhance institutional research, collaboration between producer and major consumer countries in research, improve easy access, communication and availability of academic findings, technology transfer, environmental education and management skills, extension services	10	[22][24][31][35][40][41][43][46] [47][48]
<b>Sustainability</b>		
Habitat restoration, protecting forest cover, improving and maintaining conservation, no deforestation, no development of plantation on peatland, avoid bush fire, afforestation	18	[1][22][25][30][34][36][37][42] [44][45][49][50][51][52][53][54] [55][56]
<b>Best Development Practices</b>		
Water sources free from contamination, appropriate selection of planting area, the use of pesticides, variety preparation and pre-harvest quality management, best planting techniques (lining and spacing), proper harvest and post-harvest handling, cleaner and safer transportation system, personal health and record keeping, intensification	15	[13][15][22][25][31][43][46][47] [48][49][56][57][58][59][60]
<b>Soil management</b>		
Rehabilitation on marginal land, plantation on degraded/marginal land, proper soil management, compaction of peat, minimize leaching, minimize peat oxidation	17	[1][11][15][16][21][22][24][26] [34][37][40][56][61][62][63][64][65]
<b>Water management</b>		
Irrigation where necessary, optimum ground water management, management and storage of water at 60-80 cm, minimize subsidence, field drain	16	[1][15][16][19][34][43][61][62][63] [64][67][66][68][69][70]
<b>Agroecological practices</b>		
Recycling pruned fronds to increase soil nutrient content, improve variety, planting cover crops, unidirectional leaning of palms, avoid irreversible drying, integrated pest management, precision farming	23	[1][15][21][22][24][31][34][43][44] [46][47][49][52][58][60][62][63] [70][71][72][73][74][75]

### **3. Adaptation and mitigation approaches to climate change in Malaysia**

Malaysian government at all level proposes and enacted certain adaptation and mitigation measures to climate change in different sector of the economy. Although, the impacts are felt and more devastating to agricultural sector especially oil palm, paddy, water resources, forest and biodiversity.

#### *3.1. Planting improve variety*

In the face of climate change oil palm production suffers several climatic setbacks that are new and hardly survive such new climatic changes and at the end failure might strike. However, under present climatic circumstances one of the adaptation alternatives to climate change is by planting the genetically modified improved variety that can germinate as early as possible with less water requirement and can withstand the impacts of temperature, rainfall variability and infestation of pests and diseases. These can be achieved through extensive research and development [76].

#### *3.2. Maximize water saving, infiltration and minimize evapotranspiration*

Water collection techniques such as trenches and silt pit can collect runoff water and circulate or distribute it within the plantation. These can help in saving water and keeping the soil wet at all times. Silt also helps in minimizing soil erosion, checking runoff and prevents sedimentation, maintain and improving soil fertility, make water available to the oil palm, minimize the rate of nutrients losses and helps in recycling of dissolved nutrients through infiltration and permeation. Water harvesting techniques is also another strategy that can help in saving runoff water in the plantation. This technique collects runoff and rain water and stored in a concrete reservoir for watering when necessary. Therefore, to minimize evapotranspiration the use of cover materials such as pruned frond on surface of the soil is necessary as well maintaining the standard number frond to regulate transpiration the frond surfaces and efficient drainage system to maintain water flow and water table depth to prevent flooding and sufficient utilization of irrigation to supplement moisture particularly during crop establishment.

#### *3.3. Mulching, cover cropping, intercropping*

Application of mulching materials such as manure or compost, oil palm upper layer biomass such as pruned fronds on the surface or at the plant base can help in conserving moisture and minimize evapotranspiration. Mulching materials also acts as an insulator by providing buffer from excessive heat and extreme cold, prevents weed infestation and minimize root competition, prevent soil compaction and hardening since the soil is always moist. While cover crops help in preventing soil erosion, especially surface erosion by runoff, when died and decayed improved soil physical and biological properties and supply essential nutrients to the oil palm. Cover crops help in improving soil water retention capacity making the soil always moist. Some cover crops have the ability to break the chain or cycle of pest and diseases and prevention soil compaction and hardening. Inter-cropping or mixed cropping is another adaptation strategy should in case oil palm failed. Crops such as maize can be planted between oil palm rows and serves as a means of livelihood diversification to farmers and generate extra income.

#### *3.4. Sustainable agronomic practices*

Agroecological practices such as sustainable use of recommended fertilizer can help in boosting the soil fertility and increase the FFB yield. Other techniques such as frond management to maintain the standard number of fronds to minimize the surface transpiration, application of organic manure or compost improve soil fertility and water retention capacity of the soil. Sustainable use of recommended pesticide/biological control can help in checking pest and diseases, pre-harvesting quality management of the seedlings and must be from registered dealers and designing appropriate lining and spacing of planting to maximize profit.

### 3.5. Role of extension services and adaptation

Extension service is an old tradition in agriculture and it plays a vital role in successful production. Sustainable extension services include; general capacity building to farmers, help them to achieve their target goals through on farm and off farm education to understand and adapt the recent challenges posed by climate change. The role of educating farmers is among the sound extension services, it enhances the capacity of farmers in rational thinking, adaptation choices, sustainable management and practices, negotiating the climate and decision making. Through extension agents' farmers, retailers, wholesalers, NGOs and government can create linkages and share ideas for better production. Dissemination of information and new innovations are largely through extension agents to farmers. These help in skills development. Extension agents also act as a consultant in general farm management and render good advice for sustainable production. The development and implementation of new farming policies are channelled to farmers through extension agents especially in villages and towns. Strategies such as inputs supply, markets, demand and supply, price fluctuations are strategized to farmers through extension services.

## 4. Mitigation to climate change

In recognizing the impacts of climate change, several laws, policies and regulations were enacted to minimize the impacts of climate change at national and state level. By and large in 2009 the national government came up with a policy themed "National Policy on Climate Change" mandate to ensure climate-resilient development to fulfil national aspirations for sustainability, ensure sustainable and wise management of natural resources, conservation and economic growth, strengthen resilience against climate change and enhance institutional capacity in research and development on climate change. These can be achieved through development on sustainable path, conservation of environment and natural resources, coordinated implementation, efficient participation and common but differentiated responsibilities and respective capabilities.

### 4.1. Major source of greenhouse gas emission

For the year 2014 the total emission was 317,626.83 Gg, CO<sub>2</sub> eq and the removal was 267, 147.77 Gg CO<sub>2</sub> eq and the rate of emission after accounting for removal was 50, 479.06 Gg CO<sub>2</sub> eq.

**Table 2.** GHGs emission by sector 2014 [77].

Sector	Emission/removal for 2014 (Gg CO <sub>2</sub> Eq)	Per cent emission
Energy	253,517	80%
Industrial Process	20,258	6%
Agriculture	10,851	4%
LULCF (emission)	3,317	1%
Waste	28,217	9%
Total emission	317,627	100%
Total sink	-267,148	
Net total (after subtracting sink)	50,479	

**Table 3.** Summary of mitigation strategies and the expected outcomes.

<b>The Eleventh Malaysia Plan (2016-2020)</b>	General, emphasising on sustainable economic development	Sustainable use of environment and natural resources through sustainable production and strengthening resilience against climate change and natural disaster	Enhance green growth for sustainable development and resilience	[78] [79] [80]
<b>National Policy on the Environment</b>	Environment, Water, Land, Air and Natural resources	For continuous economic, social and cultural progress and enhancement of the quality of life of Malaysians, through environmentally sound and sustainable development	Maintain status quo and improve the land productivity, clear and clean air, clean and safer water and sustainable utilization of natural resources	[81] [82]
<b>Reduce, reuse, recycle (3R) programme via the solid waste and public cleansing management act 2007, REDD+</b>	Waste management		Mandate separation of waste at household level	[83] [84]
<b>National Biofuel Policy</b>	Transportation sector	Use of environmentally friendly, sustainable and viable sources of energy to reduce the dependency on fossil fuel	Enhance prosperity and well-being of all stakeholders in the agriculture and commodity-based industries through stable and remunerative policies.	[86] [87]
<b>National Policy on Climate Change</b>	General	Mainstreaming climate change for strengthened competitiveness and improved quality of life, Integration of climate change responses into policies, plans and programmes and Strengthening of institutional and implementation capacity	Ensure climate-resilient development to fulfil National aspirations for sustainability	[84]

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<b>National Energy Policy</b>	Energy and Environment	To ensure adequate and cost-effective energy supply through alternative energy (renewable)	To minimize environmental impacts and ensure efficient utilization of energy	[77]
<b>National Policy on Biological Diversity (2016-2025)</b>	Biodiversity	Conservation and sustainable utilization of biological diversity	Reducing pressures on biodiversity, safe guarding ecosystems, species and genetic diversity and fair sharing of benefits from utilization of biological diversity.	[4]
<b>Third National Agricultural Policy (3NAP)</b>	Agriculture	To enhance food productivity and security as well as competitiveness through sustainable utilization of natural resources	Maximizing income through optimal utilization of resources in the sector	[85]

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## 5. Conclusion

The review presents the impacts of climate change on oil palm production. We highlight different impacts of climate change as well as projected impacts associated with changing climate, the adaptation and mitigation measures and new innovations to address the impacts of climate change. Adapting and mitigating impacts of climate change signifies coping to rising temperatures and extreme heat rainfall seasonality and extreme events coupled with increase infestation of pest and diseases. We specifically focused on Malaysia been the second largest producer of palm oil globally after Indonesia and its geographical location between two oceans and characterized by two seasons; northeast monsoon and southwest monsoon. Climate change has affects oil palm production directly or indirectly. The impacts manifested in the increasing trends of temperature, rainfall variability, extreme weather events and impacts of pests and diseases. Increase in temperatures reduces oil palm production by and decline in revenue. Rainfall variability destroyed oil palm plantations especially along the coastal areas through flooding and this is exacerbated by rising sea level causing decline in production and productivity. Extreme events such as El-Nino causing drought and hydrological imbalance reduce oil palm production and exacerbate water stress and high evaporation making the soil drier.

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