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CHAPTER 24

Plant adaptation strategies to climate change in Malaysian agriculture

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Abstract: Climate change poses significant effects and challenges to Malaysia's agricultural sector through rising temperatures, altered rainfall patterns, and increasing occurrences of extreme weather events. These climatic changes affect crop productivity, water availability, pest and disease dynamics, and the overall resilience of farming systems. An overview is provided of the current and projected impacts of climate change on major agricultural subsectors in Malaysia, namely rice, oil palm, rubber, and cocoa. Particular attention is given to the vulnerability of these crops to temperature stress, rainfall variability, droughts, and floods. Key adaptation strategies that can enhance agricultural resilience are examined, including the development of climate-resilient crop varieties, improved water management practices, climate-smart agriculture, and the use of climate information services and digital technologies. Sector-specific adaptation measures are discussed for rice, oil palm, rubber, and cocoa production systems. The importance of policy support, institutional strengthening, research, development, innovation, and multi-stakeholder collaboration in facilitating effective adaptation is also highlighted. Strengthening climate resilience through integrated and location-specific adaptation strategies will be essential and critical to sustaining agricultural productivity, ensuring food security, and supporting the long-term sustainability of Malaysia's agricultural sector in a changing climate.

INTRODUCTION

Climate change has emerged as one of the most pressing global challenges, with far-reaching implications for natural systems, socio-economic development, and food security. In Malaysia, the agriculture sector is particularly vulnerable to climate variability and change due to its strong dependence on climatic factors such as temperature, rainfall distribution, and seasonal stability (IPCC 2021; NRES 2024). Given its strategic role in ensuring national food supply, sustaining rural livelihoods, and supporting agro-based industries, climate-induced risks to agriculture represent a critical national concern. Global observations indicate a clear warming trend in surface temperatures alongside significant changes in precipitation patterns over the past century, reflecting the growing influence of climate change on the Earth's climate system (Figures 1 and 2).

In particular, observed and projected climatic changes, including rising temperatures, shifting rainfall patterns, and an increasing frequency and intensity of extreme weather events are already exerting measurable impacts on agricultural productivity in Malaysia (NRES 2024). These changes affect crop growth cycles, water availability, pest and disease dynamics, and livestock performance, thereby heightening risks to food security and farm income stability (FAO 2019az). Hence, a clear understanding of climate change trends and their sector-specific impacts on Malaysian agriculture is essential for guiding effective adaptation strategies and evidence-based policy interventions.

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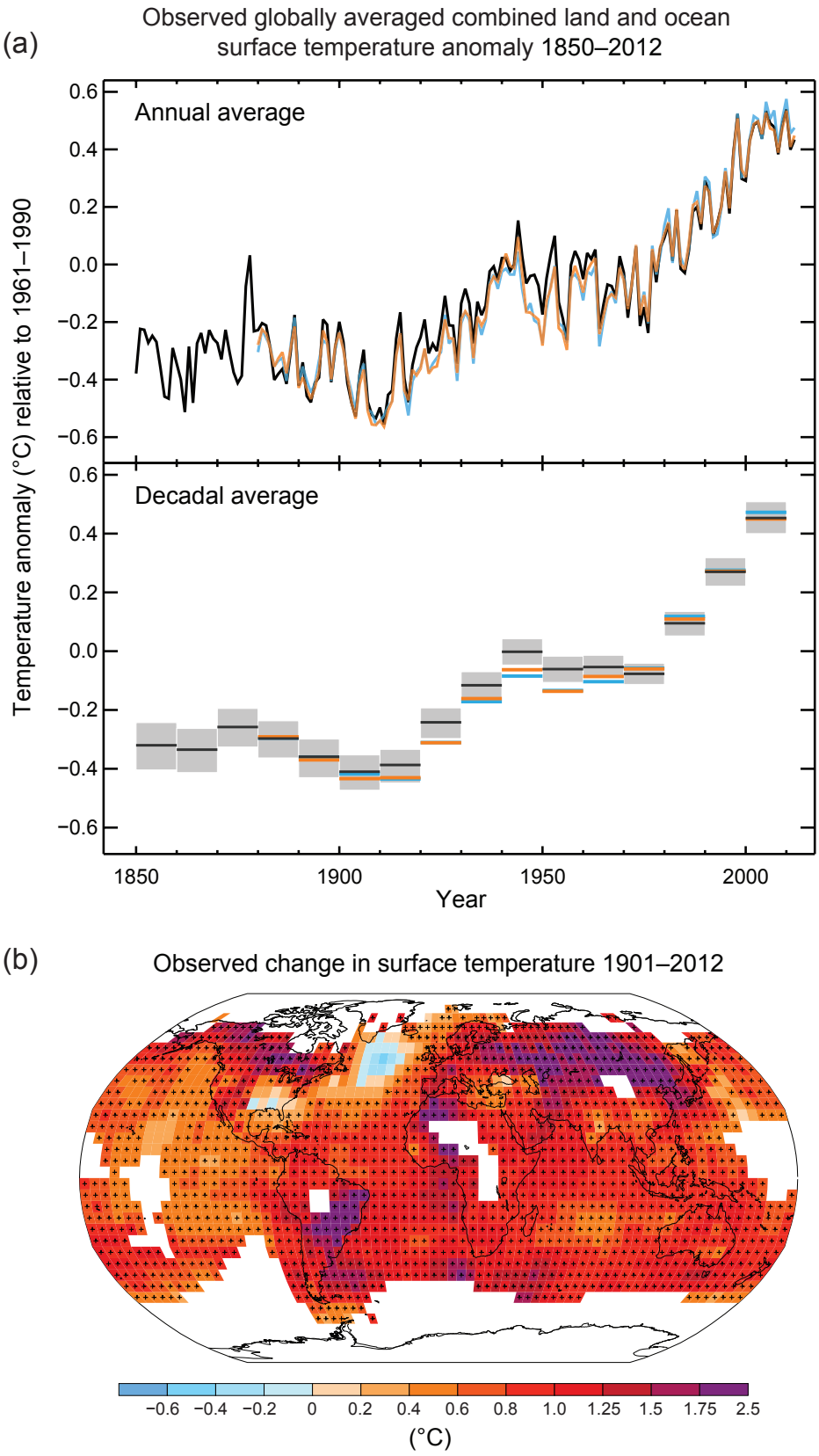


Figure 1. Global surface temperature anomalies and spatial patterns of observed temperature change during 1901–2012 (Source: IPCC 2013).

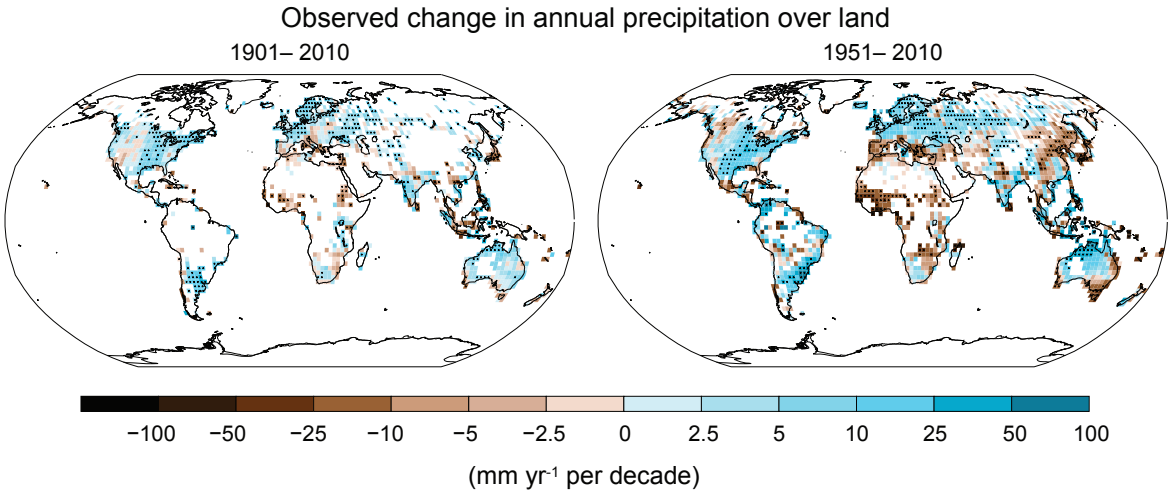


Figure 2. Spatial distribution of observed annual precipitation changes over land during 1901–2010 and 1951–2010 (Source: IPCC 2013).

In response to increasing climate variability and long-term climate change, building climate-resilient agricultural systems has become a national priority. Climate resilience in agriculture refers to the capacity of farming systems to anticipate, absorb, and adapt to climate-related stresses while sustaining productivity, ecosystem functions, and livelihoods (IPCC 2022). In the Malaysian context, strengthening resilience is particularly crucial given the sector's high sensitivity to temperature extremes, rainfall variability, and climate-related hazards such as floods and droughts.

Therefore, national policy frameworks, such as Malaysia's Fourth National Communication (NC4) Report to the United Nations Framework Convention on Climate Change (UNFCCC), underscore the importance of sector-specific and location-appropriate adaptation strategies to enhance agricultural resilience (NRES 2024). Effective adaptation extends beyond individual farm-level measures and requires an integrated approach encompassing crop genetic improvement, enhanced water and crop management, climate -smart agricultural practices, and enabling institutional and policy support. Accordingly, this section synthesises key adaptation strategies across major agricultural subsectors in Malaysia, with a particular focus on strengthening climate resilience in crop production.

OVERVIEW OF CLIMATE CHANGE IN MALAYSIA

Malaysia is located in the humid tropics and experiences relatively uniform temperatures throughout the year, with mean annual temperatures ranging between 26ºC and 28ºC and annual rainfall generally exceeding 2,000 mm (Tang 2019). Despite this apparent climatic stability, long-term observations indicate significant changes in key climate variables. According to Malaysia's NC4 to the UNFCCC, the country has experienced a clear warming trend over recent decades (Figure 3a), with mean surface temperatures increasing by approximately 0.14 – 0.25ºC per decade in some regions (NRES 2024).

In addition to rising temperatures, changes in rainfall patterns (Figure 3b) have been observed, characterised by increased variability in seasonal rainfall distribution rather than uniform changes in total annual precipitation (NRES 2024). Certain regions have experienced more intense rainfall events over shorter periods, while others are exposed to longer dry spells, thus flood and drought risk respectively. These changes are consistent with broader regional climate trends reported for Southeast Asia (IPCC 2021).

Climate projections for Malaysia indicate continued warming throughout the 21st century under both moderate and high greenhouse gas emission scenarios, accompanied by greater rainfall variability and an increased likelihood of extreme climate events (IPCC 2021; NRES 2024). These projected changes are expected to exacerbate climate risks for climate-sensitive sectors, particularly agriculture.

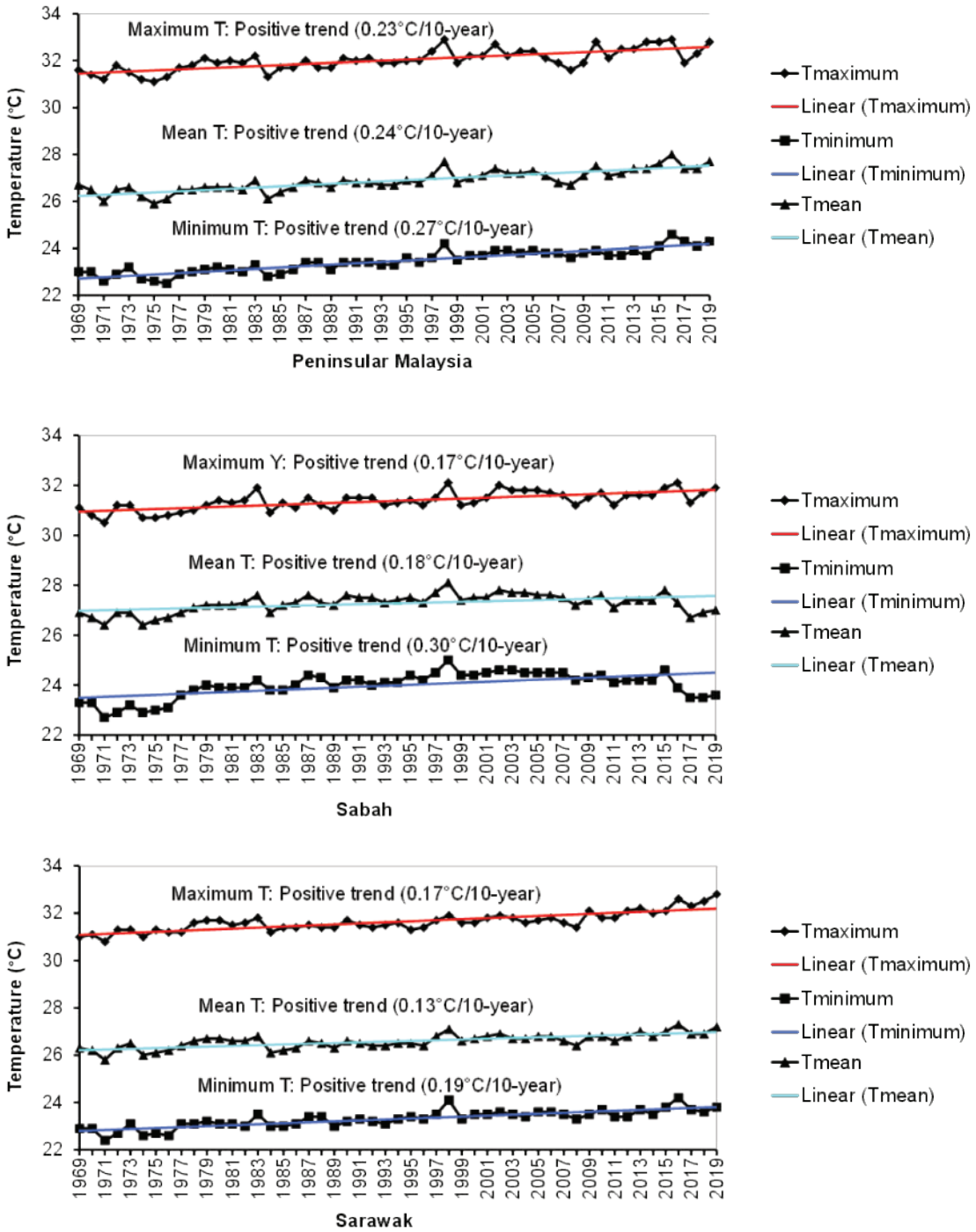
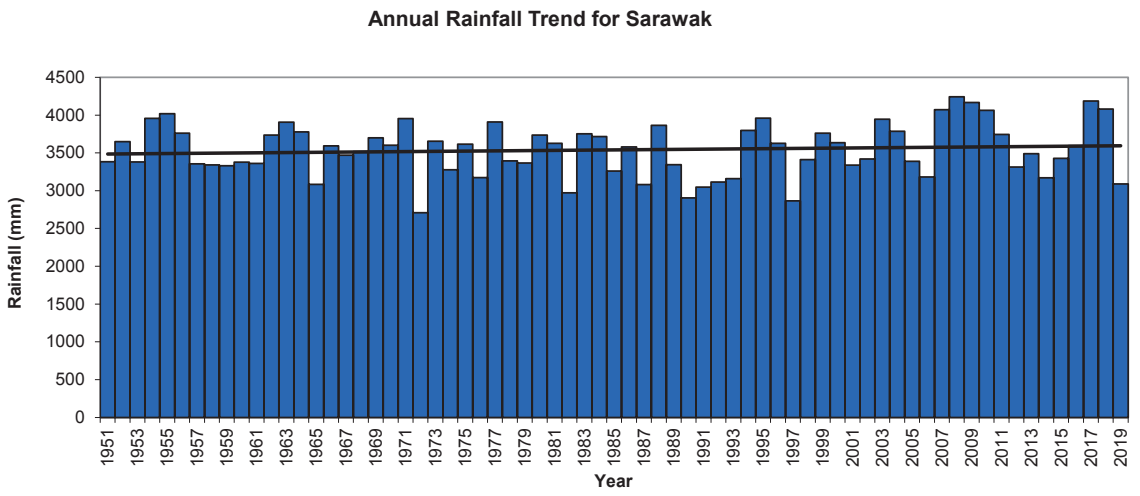
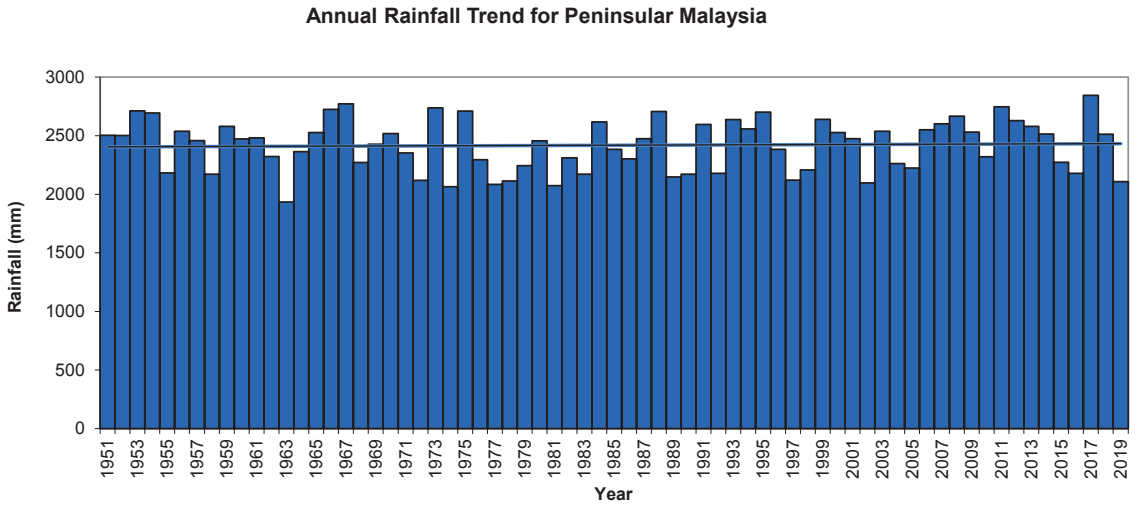


Figure 3. (a) Observed trends in annual maximum and mean minimum temperatures in Peninsular Malaysia, Sabah and Sarawak (NRES 2024).





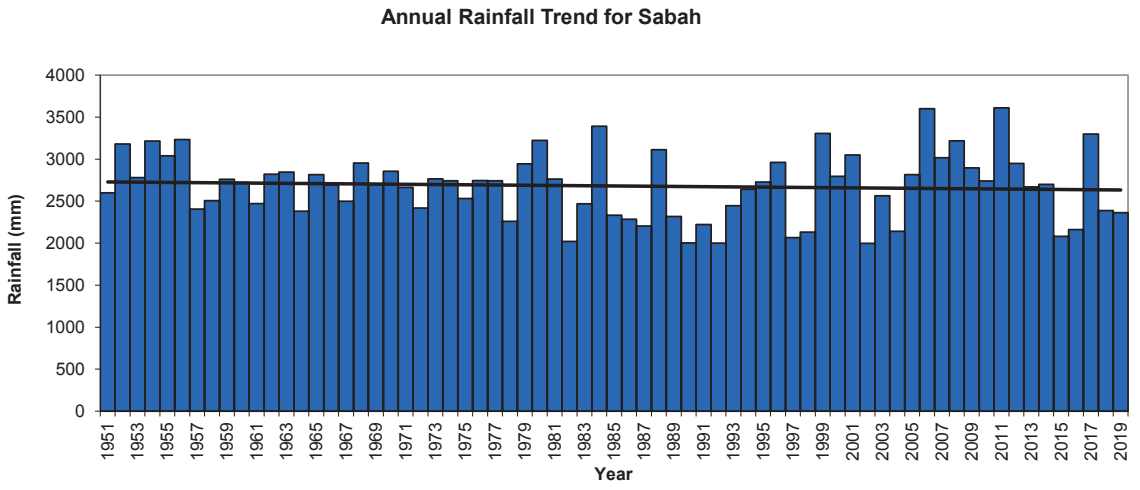


Figure 3. (b) Observed trends in annual rainfall trends in Peninsular Malaysia, Sabah and Sarawak (NRES 2024).

IMPACTS OF CHANGING CLIMATE ON THE AGRICULTURAL SECTOR

Climate change affects agriculture through multiple interconnected pathways, influencing crop physiology, water resources, soil conditions, and pest and disease dynamics. The magnitude and nature of impacts vary across subsectors depending on biological sensitivity, management practices, and agro-ecological conditions (FAO 2019b). In Malaysia, key agricultural subsectors such as rice, oil palm, rubber, cocoa, and livestock have demonstrated varying degrees of vulnerability to climate-induced stresses (NRES 2024).

Impacts on rice

Rice is Malaysia's most important staple crop and is highly sensitive to changes in temperature and water availability. Elevated temperatures, particularly during critical growth stages such as flowering and grain filling, have been associated with increased spikelet sterility, reduced grain quality, and yield losses (Peng *et al*. 2004; Wassmann *et al.* 2009). High night -time temperatures accelerate plant respiration and shorten the grain-filling period, leading to lower yields (Peng *et al.* 2004). Changes in rainfall patterns further exacerbate production risks in rice systems. Excessive rainfall and flooding can damage seedlings, disrupt field operations, and increase disease incidence, while prolonged dry spells may cause water stress, particularly in rain-fed and supplementary-irrigated areas (NRES 2024). Elevated temperatures can adversely affect rice growth throughout its life cycle, resulting in reduced survival, impaired reproductive development, lower grain yield and diminished grain quality (Figure 4). These climate-related stresses contribute to yield instability and heighten vulnerability among smallholder rice farmers.

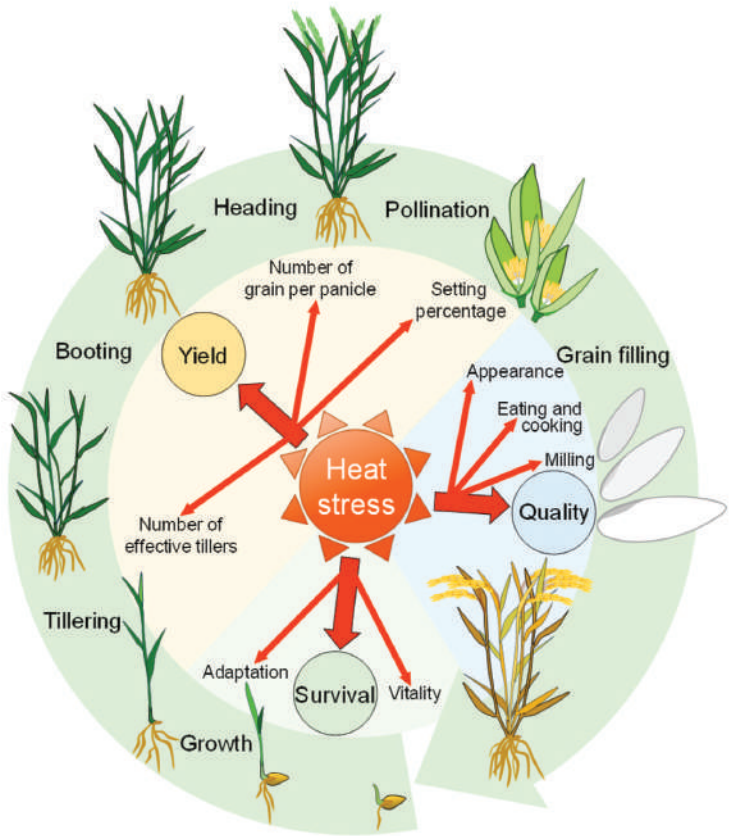


Figure 4. Continuous high temperature inhibits rice survival, yield, and quality by threatening all life stages of rice (Liu *et al.* 2025).

Impacts on oil palm

Oil palm is a major commercial or commodity crop and a key contributor to Malaysia's agricultural economy. Climate variability, particularly changes in temperature and rainfall, affects oil palm productivity by influencing flowering, fruit development, and fresh fruit bunch (FFB) formation (Corley and Tinker 2016). Prolonged periods of high temperature can induce heat stress which reduces photosynthetic efficiency and bunch yield. Rainfall anomalies, especially droughts, have been shown to reduce inflorescence initiation and increase abortion rates, often with a lagged effect on yield (NRES 2024). Conversely, excessive rainfall and flooding can impair root function and nutrient uptake, further constraining productivity. Under prolonged drought conditions, oil palm may exhibit a range of physiological and reproductive disorders, including reduced female flower production, bunch malformation, inflorescence abortion, and premature frond senescence (Figure 5). These impacts highlight the sensitivity of oil palm systems to both temperature and rainfall variability.

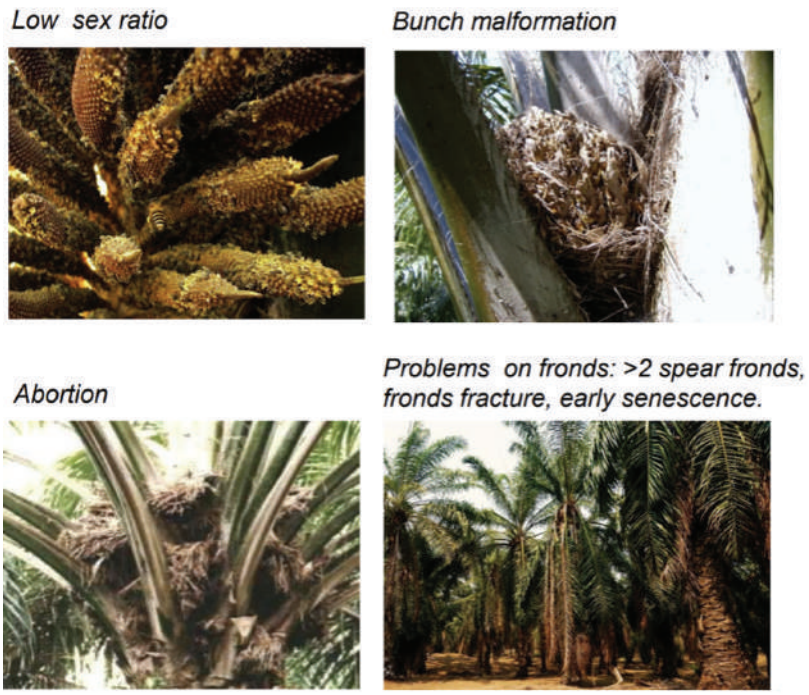


Figure 5. Effects of drought stress on oil palm, showing low sex ratio, bunch malformation, inflorescence abortion, and frond deterioration associated with prolonged water deficit (Rahutomo 2016).

Impacts on rubber

Rubber cultivation is sensitive to both rainfall variability and temperature extremes. Excessive rainfall disrupts tapping activities, reduces latex yield, and increases the incidence of fungal diseases, while prolonged dry periods can induce water stress and reduce latex flow (NRES 2024). Rising temperatures may further exacerbate physiological stress on rubber trees, affecting growth and productivity. High rainfall and prolonged humid conditions can also promote the development and spread of fungal diseases such as Pestalotiopsis leaf fall disease, which may reduce tree vigour and latex production (Figure 6). Extreme events such as floods and droughts can also cause physical damage to plantations and increase tree mortality, posing significant risks to the smallholder livelihoods that dominate Malaysian rubber production.



Figure 6. Rubber tree leaves infected by *Pestalotiopsis* leaf fall disease, a fungal disease favoured by prolonged periods of high rainfall and humidity (The Stringer 2021).

Impacts on cocoa

Cocoa production is highly sensitive to microclimatic conditions, requiring relatively stable temperature and moisture regimes. Increased temperatures and prolonged dry periods can lead to flower and pod abortion, reduced bean quality, and increased susceptibility to pests and diseases (Schroth *et al.* 2016). Changes in rainfall patterns may also increase the prevalence of diseases such as black pod, further threatening cocoa yields (NRES 2024). Black pod rot caused by *Phytophthora palmivora* is among the most destructive diseases affecting cocoa and is often favoured by prolonged wet and humid conditions (Figure 7). Given its climatic sensitivity, cocoa production in Malaysia is expected to face increasing challenges under future climate change scenarios, particularly in areas experiencing greater rainfall variability.



Figure 7. Black pod rot disease caused by *Phytophthora palmivora*, one of the most destructive diseases affecting cocoa production and a disease favoured by warm and humid environmental conditions (Vanegtern *et al*. 2015).

ADAPTATION STRATEGIES FOR CLIMATE-RESILIENT AGRICULTURE IN MALAYSIA

To address the growing risks posed by climate variability and long-term climate change, Malaysia has increasingly focused on developing and implementing adaptation strategies to enhance the resilience of its agricultural systems. Given the diversity of agro-ecological conditions and the varying sensitivity of crops to climate stressors, adaptation measures must be sector-specific, location-appropriate, and integrated across multiple levels of management.

In the agricultural context, effective adaptation encompasses crop genetic improvement, climate-responsive water and crop management, climate-smart farming practices, and enabling institutional and policy support. The key adaptation strategies for major agricultural subsectors in Malaysia, particularly rice, oil palm, rubber, and cocoa, namely, practical measures and strategic interventions, strengthen adaptive capacity, safeguard productivity, and support the long-term sustainability of national food and commodity production under a changing climate.

Adaptation Strategies for Rice

Rice is highly sensitive to climate stressors such as heat, drought, and flooding, particularly during critical growth stages. Adaptation strategies for rice production in Malaysia, therefore, focus on enhancing tolerance to climatic stresses while improving resource-use efficiency and management flexibility.

Crop genetic improvement and plant breeding play a central role in enhancing rice resilience to climate change. Breeding efforts have focused on developing varieties with improved tolerance to high temperatures, drought, and submergence, as well as varieties with shorter growth durations that reduce exposure to climatic risks (Wassmann *et al.* 2009; Mohanty *et al.* 2013). Heat-tolerant rice varieties are particularly important in addressing yield losses associated with elevated daytime and nighttime temperatures, which can cause spikelet sterility and reduce grain filling (Peng *et al*. 2004). Similarly, the development of drought-tolerant and submergence-tolerant varieties helps mitigate yield losses under increasingly variable rainfall conditions. Advances in molecular breeding, marker-assisted selection, and genomics have further accelerated the development of climate-resilient rice varieties, enabling more targeted and efficient breeding programmes (Mohanty *et al*. 2013). In Malaysia, national breeding programmes led by research institutions such as MARDI have contributed to the development and dissemination of improved rice varieties adapted to local agro-climatic conditions, forming a critical pillar of climate adaptation in the rice sector (NRES 2024).

Water management is a key adaptation strategy for rice production under changing rainfall patterns and increasing water scarcity. Improved irrigation efficiency and adaptive water management practices help reduce vulnerability to both drought and flooding. One widely promoted approach is Alternate Wetting and Drying (AWD), also known as Safe AWD, which involves periodic drying of paddy fields rather than continuous flooding, thereby reducing water use while maintaining yields (FAO 2017). Figure 8 shows the Safe AWD research plot at MARDI Seberang Perai, Pulau Pinang, conducted by Malaysian Agricultural Research & Development Institute (MARDI) in 2024. Climate-informed irrigation scheduling, supported by weather forecasts and seasonal climate outlooks, further enhances farmers' capacity to manage water more effectively under variable conditions. In irrigated rice systems, improved canal management, on-farm water control, and infrastructure maintenance are also critical adaptation measures to ensure a reliable water supply during dry periods and minimise flood-related damage during extreme rainfall events (NRES 2024).

Climate-smart crop management practices complement genetic and water-based adaptation strategies by improving overall system resilience. These practices include adjustments in planting dates to avoid exposure to heat stress or excessive rainfall, integrated nutrient management to maintain soil fertility under changing conditions, and improved pest and disease management in response to climate-induced shifts in pest dynamics (FAO 2019b). The use of climate information services, digital advisory tools, and early warning systems enables farmers to make informed decisions regarding planting, fertiliser application, and harvest timing. Collectively, these climate-smart practices enhance adaptive capacity while contributing to productivity and sustainability in rice-based farming systems.



(a) Safe AWD research plot (b) Gas sample collection (c) Monitoring of field water level

Figure 8. Safe AWD research plot at MARDI Seberang Perai, Pulau Pinang in 2024.

Adaptation strategies for oil palm

Adaptation strategies for oil palm focus on improving tolerance to heat and water stress, enhancing plantation management, and strengthening institutional support systems. According to the NC4, breeding and selection of oil palm varieties with improved tolerance to drought and heat stress are important long-term adaptation measures (NRES 2024).

At the plantation level, improved soil and water conservation practices, such as mulching, terracing, and effective drainage systems, help reduce moisture stress and minimise damage from extreme rainfall events (Figure 9). Diversification of planting materials, improved fertiliser management, and better pest and disease monitoring also help reduce climate-related risks. Strengthening advisory services and integrating climate risk information into plantation management planning further support adaptive capacity in the oil palm sector.



Figure 9. Plantation-level adaptation measures, including mulching and terracing, support more stable growing conditions under changing climate patterns. (Source: Applied Agricultural Resources Sdn. Bhd.)

Adaptation strategies for rubber

Rubber adaptation strategies emphasise improved planting materials, flexible management practices, and risk reduction measures. The use of climate-resilient rubber clones with enhanced tolerance to drought and disease is highlighted in NC4 as a key adaptation pathway (NRES 2024). A previous study found that the RRIM3001 rubber clone exhibited superior tolerance to soil moisture deficits, highlighting its potential as a drought-resilient clone that can enhance the sustainability and climate resilience of rubber production in water-scarce regions of Malaysia (Rohaizad *et al.* 2024) (Figure 10).

Management-based adaptations include adjusting tapping schedules during periods of excessive rainfall, implementing soil moisture conservation practices, and improving drainage to reduce flood damage. Agroforestry and intercropping systems have also been promoted as adaptation options to diversify income sources and improve microclimatic conditions within rubber plantations.



Figure 10. RRIM 3001 clone, commonly referred to as the "1Malaysia" clone, was bred in 1976 through controlled hand pollination between IAN 873 (female parent) and PB 235 (male parent), under a breeding programme conducted by the former Malaysian Rubber Board. (Source: Hosnan 2014).

Adaptation strategies for cocoa

Cocoa adaptation strategies focus on mitigating heat and moisture stress through improved farm management and crop diversification. Shade management, through agroforestry systems, is a critical adaptation strategy that helps regulate temperature, reduce evapotranspiration, and improve soil moisture retention (Schroth *et al*. 2016).

Additional measures include the use of improved cocoa varieties with greater tolerance to climatic stress, enhanced soil fertility management, and integrated pest and disease control to address climate-induced increases in disease pressure. These strategies are consistent with the adaptation priorities outlined in NC4 for climate-sensitive perennial crops (NRES 2024). The findings of Osman *et al.* (2017) highlighted MCBC 1, MCBC 4, MCBC 5, MCBC 6, MCBC 8, and MCBC 9 as promising drought-and water-stress-tolerant clones, with MCBC 10 and MCBC 3 showing tolerance to drought and water stress, respectively (Figure 11).

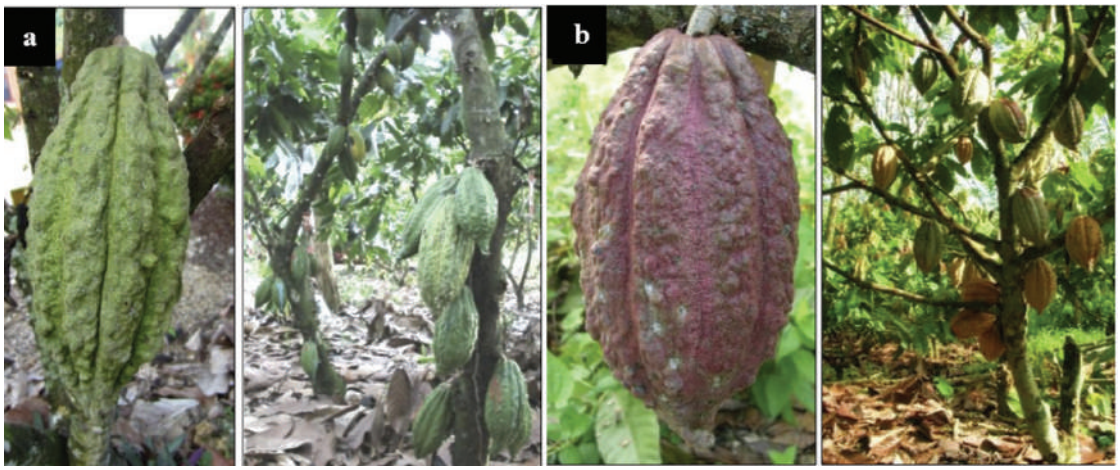


Figure 11. MCB cocoa clones. **(a)** MCBC 5 and **(b)** MCBC 6 are among the clones that showed tolerance to both drought and water stress conditions in Malaysia.

INTEGRATION, POLICY SUPPORT AND FUTURE DIRECTIONS

Effective adaptation to climate change in agriculture requires an integrated and coordinated approach that links scientific innovation, farm-level practices, institutional capacity, and policy support. Isolated adaptation measures, while beneficial, are often insufficient to address the complex and interconnected risks posed by climate change. In Malaysia, strengthening climate-resilient agriculture therefore depends on integrating adaptation strategies across crops, livestock systems, and scales of governance.

National policy frameworks provide an important foundation for supporting agricultural adaptation. Malaysia's Fourth National Communication (NC4) Report to the UNFCCC highlights agriculture as a climate-sensitive sector and emphasises the need to mainstream climate change adaptation into agricultural planning, research, development and innovation, and extension services (NRES 2024). Alignment with broader national and international frameworks, including Climate-Smart Agriculture (CSA) principles and the Sustainable Development Goals (SDGs), further reinforces the integration of adaptation, productivity, and environmental sustainability objectives.

Institutional support plays a critical role in enabling the adoption and scaling of adaptation strategies. Strengthening agricultural research systems, extension services, and climate information delivery is essential to ensure that climate-resilient technologies and practices reach farmers effectively. The use of climate services, such as seasonal forecasts and early warning systems, can enhance decision-making related to planting schedules, water management, and risk reduction. Capacity building for farmers and extension officers is equally important to improve awareness, technical knowledge, and adaptive capacity at the local level.

Looking forward, future adaptation efforts in Malaysia should prioritise innovation, inclusivity, and long-term resilience. Continued investment in climate-resilient crop breeding, digital agriculture, and data-driven decision-support tools will be essential and crucial for addressing emerging climate risks. Greater emphasis should also be placed on strengthening multi-stakeholder collaboration among government agencies, research institutions, the private sector, and farming communities. Integrating adaptation with mitigation co-benefits, where feasible, can further enhance the sustainability of agricultural systems. Collectively, these directions will be vital for ensuring that Malaysia's agricultural sector remains productive, resilient, and sustainable under a changing climate.

CONCLUSION

Climate change poses a systemic and escalating risk to Malaysia's agricultural sector. Rising temperatures, shifting rainfall patterns, and the increasing frequency of extreme weather events are already affecting crop productivity, livestock performance, and farm livelihoods across key agricultural subsectors (IPCC 2021; NRES 2024). Although the severity and nature of impacts vary among production systems and locations, the evidence clearly indicates that climate change threatens the long-term sustainability, resilience, and reliability of national food production. These challenges underscore the urgent need for targeted, sector-specific adaptation strategies to reduce vulnerability and strengthen resilience within Malaysia's agricultural sector. Effective adaptation is critical for safeguarding agricultural productivity, rural livelihoods, and national food security. In this regard, a combination of crop genetic improvement, enhanced water and crop management, climate-smart agriculture practices, and supportive institutional and policy frameworks forms the foundation of climate-resilient agricultural systems. While notable progress has been made in advancing adaptation efforts, continued investment in research, development, and innovation, capacity building, and policy integration remains essential to address emerging and future climate risks. By adopting integrated and location-appropriate adaptation strategies across major agricultural subsectors, Malaysia can enhance the resilience and sustainability of its agricultural systems and better position the sector to withstand the challenges of a changing climate.

REFERENCES

Applied Agricultural Resources Sdn. Bhd. n.d. Soil Management: Soil and Water Conservation Management. *AA Resources*. https://aarsb.com.my/soil-management-soil-and-water-conservation-management

Corley, R.H.V. and Tinker, P.B. 2015. The climate of the oil palm-growing regions. In *The Oil Palm. 5th Edition*, pp. 56–67. Chichester: Wiley-Blackwell.

FAO. 2017. *Water Management in Rice in Asia: Some Issues and Challenges*. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2019a. *Climate Change and Livestock*. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2019b. *Climate-Smart Agriculture Sourcebook*. Rome: Food and Agriculture Organization of the United Nations.

Hosnan, M.A. 2014, May 14. GETAH - KLON 1 MALAYSIA? *Anim Agro Technology*. https://animhosnan.blogspot.com/2014/05/getah-klon-1-malaysia.html

IPCC. 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (Eds.). Cambridge: Cambridge University Press.

IPCC. 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud *et al.* (Eds.). Cambridge: Cambridge University Press.

IPCC. 2022. *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig *et al*. (Eds.). Cambridge: Cambridge University Press.

Liu, H., Wei, Y., Xia, S., Xie, W., Ren, D. and Rao, Y. 2025. Improvements in tolerance to heat stress in rice via molecular mechanisms and rice varieties. *Agriculture* 15(3): 318. https://doi.org/10.3390/agriculture15030318

Mohanty, S., Wassmann, R., Nelson, A., Moya, P. and Jagadish, S.V.K. 2013. *Rice and Climate Change: Significance for Food Security and Vulnerability. IRRI Discussion Paper Series No. 49*. Los Baños: International Rice Research Institute.

NRES. 2024. *Malaysia Fourth National Communication (NC4) to the United Nations Framework Convention on Climate Change*. Putrajaya: Ministry of Natural Resources and Environmental Sustainability.

Osman, R., Ramba, H. and Ling, A.S.C. 2017. Preliminary assessment on drought tolerance characteristics of some Malaysian cocoa planting materials, *Indonesian International Cocoa Symposium*, 18-21 October 2017, Grand Sahid Jaya, Jakarta.

Peng, S., Huang, J., Sheehy, J.E., Laza, R.C., Visperas, R.M., Zhong, X., Centeno, G.S., Khush, G.S. and Cassman, K.G. 2004. Rice yields decline with higher night temperature from global warming. *Proceedings of the National Academy of Sciences of the United States of America* 101(27): 9971–9975. https://doi.org/10.1073/pnas.0403720101

Rahutomo, S. 2016. BMP's for Facing Drought Stress on Oil Palm, *Field Clinic and Colloquium of the International Society of Oil Palm Agronomists (ISOPA)*, Marihat, Indonesia, 29 September 2016. https://agroklimatologippks.com/wp-content/uploads/2016/10/iopri-presentation-on-isopa-2016_rev01_may.pdf

Rohaizad, M., Zulkefly, S., Siti, N.A.A., Mohd Razi, I., Sarker Mohammad, R.K., Mohd Aswad, A.W. and Aizat Shamin, N. 2024. Physiological behavior of rubber plants (*Hevea brasiliensis*) to different soil moisture conditions. *Pertanika Journal of Science and Technology* 32(6): 2807–2826.

Schroth, G., Läderach, P., Martinez-Valle, A.I., Bunn, C. and Jassogne, L. 2016. Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation. *Science of the Total Environment* 556: 231–241.

Tang, K.H.D. 2019. Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. *Science of the Total Environment* 650: 1858–1871. https://doi.org/10.1016/j.scitotenv.2016.03.024

The Stringer. 2021, July 17. Fungal infection can render rubber trees unable to produce much latex, posing damaging risks to smallholders, manufacturers. *The Stringer*. https://thestringer874585516.wordpress.com/2021/07/17/fungal-infection-can-render-rubber-trees-unable-to-produce-much-latex-posing-damaging-risks-to-smallholders-manufacturers

Vanegtern, B., Rogers, M. and Nelson, S. 2015. Black pod rot of cacao caused by *Phytophthora palmivora*. In *CTAHR Plant Disease Publication, PD-108*. Honolulu: College of Tropical Agriculture and Human Resources, University of Hawai‘i at Mānoa. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-108.pdf

Wassmann, R., Jagadish, S.V.K., Heuer, S., Ismail, A.M., Redona, E., Serraj, R., Singh, R.K. *et al*. Climate change affecting rice production: The physiological and agronomic basis for possible adaptation strategies. In *Advances in Agronomy, Vol. 101*, D.L. Sparks (Ed.), pp. 59–122. Burlington: Academic Press.