Global Water Partnership

Drought Conditions and Interventions in Southeast Asia

Regional Desktop Study of Drought Conditions and Interventions in Southeast Asia 2025

Southeast Asia Regional Office Secretariat

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Disclaimer

Acknowledgement

This study was conducted as part of the Climate Risk and Early Warning Systems (CREWS) initiative, under the project entitled: “Reinforcing the Capacities of Meteorological and Hydrological Services and Enhancing the Early Warning Systems in Cambodia and Lao People’s Democratic Republic (PDR)”. It is an initiative led by national institutions and supported by the World Meteorological Organisation (WMO), the UN Office for Disaster Risk Reduction (UNDRR), and the World Bank (WB).

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1. Project Overview

1.1. Background

The Climate Risk and Early Warning Systems (CREWS) initiative has launched a crucial project titled "Reinforcing the Capacities of Meteorological and Hydrological Services and Enhancing the Early Warning Systems in Cambodia and Lao People's Democratic Republic (PDR)." The project's objective is to enhance the capabilities of national and regional institutions to deliver effective and inclusive risk-informed early warning services to vulnerable populations in Cambodia and Lao PDR.

Officially launched in October 2021, it is a four-year project that will conclude in July 2025. Spearheaded by each country's national institutions, the project receives support from key international organisations such as the World Meteorological Organisation (WMO), the United Nations Office for Disaster Risk Reduction (UNDRR), and the World Bank (WB). It builds upon ongoing regional initiatives, fostering active engagement with key regional stakeholders.

Throughout the project's duration, the National Meteorological and Hydrological Services (NMHSs) and National Disaster Management Offices (NDMOs) of both Cambodia and Lao PDR, in collaboration with regional partners, are addressing gaps across the four pillars of Early Warning Systems:

1. Strengthened governance mechanisms, including policies, strategic frameworks, institutional mechanisms, and enabling environment of national and regional stakeholders
2. Enhanced the capacity of NMHSs to provide accurate forecasts and timely warnings.
3. Strengthened Information and Communication Technology capabilities of NMHSs.
4. Improved preparedness and response capabilities to act upon warning and risk information, with the goal to minimise the impact of disasters on lives, livelihoods, and socio-economic systems.

As the CREWS project progresses in Cambodia and Lao PDR, it has become evident that a broader understanding of drought management in Southeast Asia is crucial. Droughts represent a significant climate-related challenge in the region, affecting agriculture, water resources, and overall socio-economic stability. The varying approaches to drought management across Southeast

Asian countries, including differences in policies, strategies, and action plans, provide a context for improving early warning systems and climate resilience strategies. This regional perspective is particularly valuable for enhancing the effectiveness of the CREWS project in Cambodia and Lao PDR, as it allows for the integration of best practices and lessons learned from neighbouring countries facing similar challenges.

1.2. Objective

The regional drought desktop study in Southeast Asia aims to establish a comprehensive climate rationale for the CREWS project in the region. It collected essential baseline information on drought management, such as 1) the prevalent drought conditions and their types in Southeast Asia, 2) the impact of climate change on drought conditions, and 3) the economic and social losses of communities and ecosystems caused by drought.

The study reviewed existing interventions to mitigate drought impacts and proposed forward-looking recommendations. By examining these aspects, the research will provide valuable insights into the drought landscape in Southeast Asia, assess the effectiveness of current drought management strategies, and offer guidance for enhancing drought resilience in the region through the CREWS project and other future initiatives.

1.3. Scope of Study

This study utilised secondary data from regional publications, official national government statistics, and relevant development organisations. Coordination with climate experts from GWP Headquarters and Country Water Partnerships in Southeast Asia was conducted through online meetings or questionnaires to gather comprehensive information. The findings were presented in a webinar or meeting organised by GWP-SEA, involving country water partnerships and relevant stakeholders, to inform participants about the current landscape of drought management and policies in Southeast Asia. Additionally, these meetings served as a platform to collect feedback and inform future actions to address drought in the region.

2. Understanding Drought in Southeast Asia

Figure 1. Water Depletion Due to Drought in Botok Dam, Sragen, Indonesia

Source: ANTARA FOTO, 2018

2.1. Definition and Characteristics of Drought

As defined by the World Meteorological Organisation (WMO), drought refers to a prolonged period of abnormally dry weather that depletes water resources. This phenomenon results from a deficiency of precipitation over an extended timeframe, leading to an imbalance between water availability and demand (WMO, 2023). Drought is not merely a physical event but also a relative one, varying in impact depending on the region's usual climate conditions. For example, what constitutes a drought in a humid area may differ significantly from that of an arid region.

Droughts are characterised by their severity, duration, and spatial extent. The severity is determined by the degree of moisture deficit relative to the normal levels of a specific region, while duration refers to the length of the dry period. The spatial extent covers the geographical area affected by the drought (Integrated Drought Management Programme (IDMP), 2022).

2.2. Typology of Drought

Droughts can also be categorised into different types based on their triggering mechanisms: meteorological drought, agricultural drought, hydrological drought, and socio-economic drought.

2.2.1. Meteorological Drought

Meteorological drought is defined as a prolonged period of below-average precipitation. Meteorological drought is typically the first indicator of drought conditions, as it reflects the direct absence of rainfall or snow over a region (NOAA, n.d.). The severity of meteorological drought is measured using the Standardised Precipitation Evapotranspiration Index (SPEI), which assesses moisture conditions based on precipitation, evaporation, and temperature variations (Illarionovna, 2024).

2.2.2. Agricultural Drought

Agricultural drought occurs when there is insufficient soil moisture to meet the needs of crops during the growing season (NOAA, n.d.). This type of drought is closely tied to meteorological drought but focuses specifically on the impact on agriculture (Wang et al., 2024). Soil moisture is crucial for maintaining healthy crops, as it supports plant roots in absorbing water and nutrients necessary for growth. When precipitation is inadequate, soil moisture begins to deplete, and if this condition persists, it leads to stress on crops (Fu et al., 2022).

2.2.3. Hydrological Drought

Hydrological drought is characterised by a decline in water levels within natural water bodies, including rivers, lakes, reservoirs, and groundwater systems (NOAA, n.d.). This type of drought often occurs due to prolonged meteorological droughts, where reduced precipitation limits runoff and groundwater recharge. The decreased water availability in these natural sources can significantly affect various sectors, such as agriculture, industry, and domestic use (Peña-Guerrero et al., 2020).

2.2.4. Socio-economic Drought

Socio-economic drought occurs when the water demand exceeds the available supply due to the combined effects of the other types of drought (NOAA, n.d.). This type of drought emphasises the human and economic impacts of water shortages. It affects industries, households, and communities, leading to water rationing, increased competition for water resources, and significant economic losses (Liu et al., 2020). Socio-economic drought can also exacerbate social inequalities, as marginalised populations are often more vulnerable to water scarcity and its associated impacts (Israilova et al., 2023). This type of drought underscores the interconnectedness of environmental, economic, and social systems.

2.3. Three Drought Management Pillars

The Integrated Drought Management Programme (IDMP) proposed three pillars designed to promote comprehensive drought management, i.e., 1) Drought Monitoring and Early Warning Systems (DEWS), 2) Drought Risk and Impact Assessments, and 3) Drought Risk Mitigation, Preparedness, and Response. These pillars were established during the High-Level Meeting on National Drought Policy (HMNDP) in Geneva in 2013, providing a framework to tackle the challenges of drought more effectively (WHO, 2013).

The first pillar, Drought Monitoring and Early Warning Systems (DEWS) forms the bedrock of proactive drought management. DEWS focuses on monitoring climate and water supply trends and identifying drought onset, likelihood, and severity. It is a key tool to trigger pre-emptive actions outlined in a drought management plan. Essential to DEWS are several components: a) continuous observation and monitoring efforts aim to collect critical data; b) filling spatial and temporal gaps to gauge drought indices accurately; c) improving capabilities of prediction and forecasting to provide more reliable monthly, sub-seasonal and seasonal drought outlooks; d) dissemination of research and planning tools; and e) effective communication and outreach to equip communities with the knowledge needed to reduce vulnerability.

The second pillar, Drought Risk and Impact Assessments focuses on identifying the most significant historical, current, and potential future impacts of drought to reduce vulnerability. Central to this process is a thorough analysis of the root causes behind drought-related impacts. Drought vulnerability is assessed through ongoing monitoring, evaluating immediate impacts, and projecting future losses. The assessment itself spans three dimensions. First, a people-centred approach examines how drought affects livelihoods, such as income, assets, and the resilience of communities and individuals. Second, water-balance assessments focus on understanding water availability and comparing water stocks and flows with consumption patterns to ensure sustainable usage. Third, land-based assessments investigate the effects of drought on crop production and other ecosystem services, particularly under changing climatic conditions and varying water supply scenarios.

The third pillar, Drought Risk Mitigation, Preparedness, and Response, aims to reduce both vulnerability and the overall impacts of drought. Mitigation involves implementing long-term strategies to lessen exposure to drought, while preparedness focuses on ensuring plans and resources are in place before a drought occurs. Response actions are taken during and after a drought to manage the immediate crisis and aid recovery efforts. Measures that support this pillar include proactive steps such as enhancing water storage and supply systems, managing water demand, promoting public awareness, adapting crop varieties, and ensuring effective land use planning. In addition to these forward-thinking efforts, reactive measures such as financial aid, emergency water provision, and food and feed relief are critical for managing the aftermath of drought events.

2.4. Climate Change Impacts to Drought

Climate change is intensifying the frequency, duration, and severity of droughts across the globe, significantly altering the natural water cycle. As global temperatures rise, evaporation rates increase, leading to more significant moisture loss from soils, plants, and water bodies (Tripathy et al., 2023). This shift exacerbates existing drought conditions and contributes to more prolonged and severe drought events, particularly in regions already prone to water scarcity (Chiang et al., 2021; Hosseinizadeh et al., 2015). Moreover, climate change disrupts traditional precipitation patterns, causing some areas to experience reduced rainfall while others may see more intense but less frequent rainfall events. This irregularity in precipitation further complicates water management and increases the risk of droughts and floods, sometimes even within the same region (Ehtasham et al., 2024; Met Office, n.d.).

The relationship between climate change and drought is also evident in the shifting boundaries of arid and semi-arid regions. As temperatures continue to rise, once relatively humid regions may become more susceptible to drought, while already dry areas are likely to face even harsher conditions (Patel & Patel, 2024; Stringer et al., 2021). This trend is particularly concerning for agricultural regions, where stable weather patterns are crucial for crop planning and food production. In addition, climate change-induced droughts can lead to a cascade of environmental impacts, including reduced groundwater recharge, loss of biodiversity, and increased incidence of wildfires (Food and Agriculture Organization (FAO), 2016). These changes underscore the need for adaptive water management strategies and enhanced drought resilience to mitigate the impacts of a warming climate.

2.5. Impact of Drought on Social, Economic, and Environmental Aspects

The prolonged impact of drought significantly affects various aspects, specifically ones related to the social, economy, and environment. In the economic aspects, the World Bank Group's Water Global Practice has proven drought has material impacts on GDP per capita growth rates which are sharper in low-income and middle-income countries, as in agriculture-dominated areas of the developing world (Zaveri et al., 2023). Agricultural communities are exceptionally vulnerable to drought. For example, drought could threaten food production through crop damage and yield decreases caused by environmental degradation, leading to reduced economic growth and food insecurity. However, it is not just the food sector that is threatened by increased drought risks. In terms of energy production, the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) explicates that there is a medium confidence the current global thermoelectric and hydropower production has been negatively affected by droughts, with around 4 to 5% reduction in plant utilisation rates during drought years compared to long-term average values since the 1980s (Caretta et al., 2022).

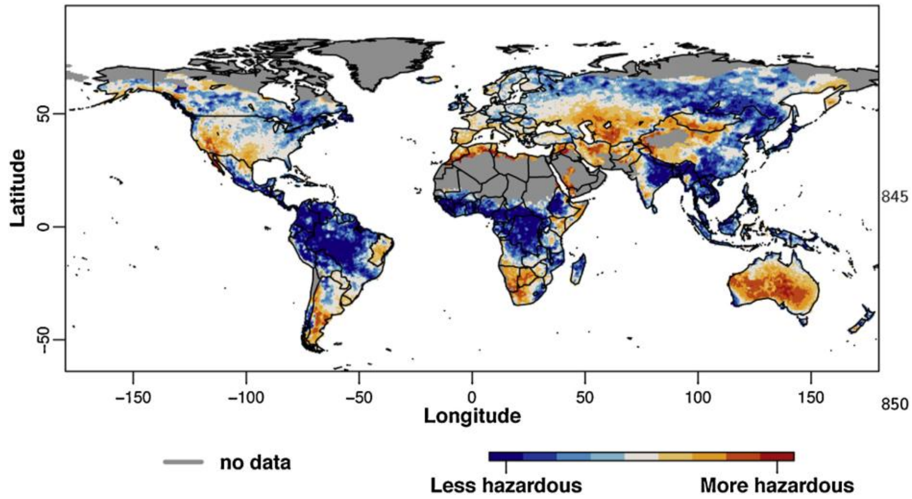
In terms of the social and environmental aspects, drought could cause human displacements and ecosystem disruptions. Drought impact to migration would carry hefty negative consequences to people who are migrating, especially to unsafe settlements. Additionally, migrants in their new settlements often face various challenges such as a loss of social ties, sense of place, and cultural identity (Serdeczny et al., 2018). Furthermore, it may come along with the ecological impacts of drought, including water stress for vegetation and a potential increase in wildfires that can cause the deaths of people and large numbers of animals, impacting the habitats of threatened species that contribute to ecosystem degradation and biodiversity loss (Caretta et al., 2022).

3. Drought Occurrences in Southeast Asia (SEA) countries

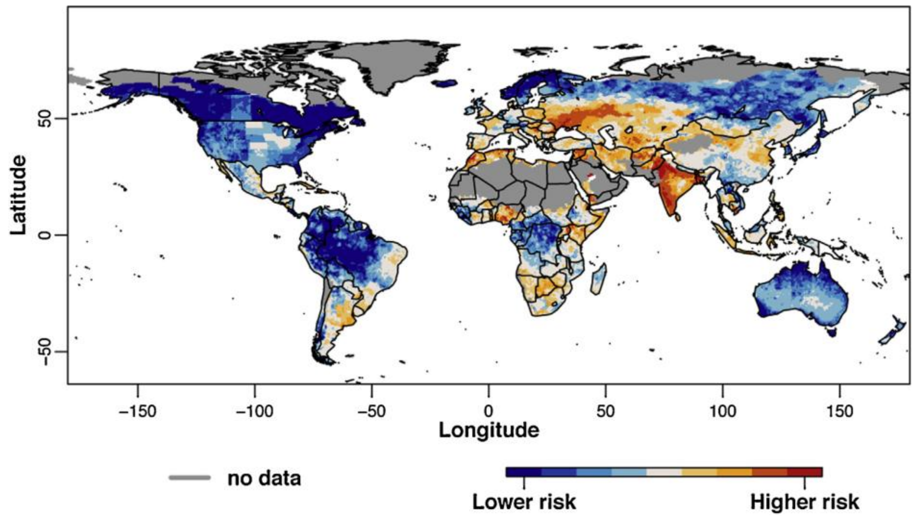
Globally, Southeast Asia experiences fewer drought events compared to regions such as the Middle East, Australia, South Africa, parts of the Americas, and Europe. This is largely due to its tropical climate, which typically sees more consistent rainfall throughout the year. In contrast, regions like the Middle East and Australia have arid and semi-arid climates, making them more prone to prolonged dry periods and severe drought conditions. Europe's Mediterranean region and parts of the U.S. also face significant drought risks due to seasonal variations in rainfall and increasing climate change impacts. Southeast Asia's proximity to large bodies of water and its more humid environment contribute to its relative resilience against drought compared to these regions.

Southeast Asia's economic structure, which relies on agriculture such as rice cultivation, faces difficulty due to the limited practice of efficient water and sustainable farming. Other factors pressure on water availability and quality include rapid urban expansion, inadequate access to water infrastructure, and poor water management. As a result, Southeast Asia is classified as having a medium to high drought risk.

While it may not experience droughts as frequently as more arid regions, its socio-economic conditions, combined with the looming threats of climate change, increase the severity of potential impacts when droughts occur. Risk level in SEA underscores the importance of implementing effective water management and climate adaptation strategies to mitigate future drought risks.



(a)



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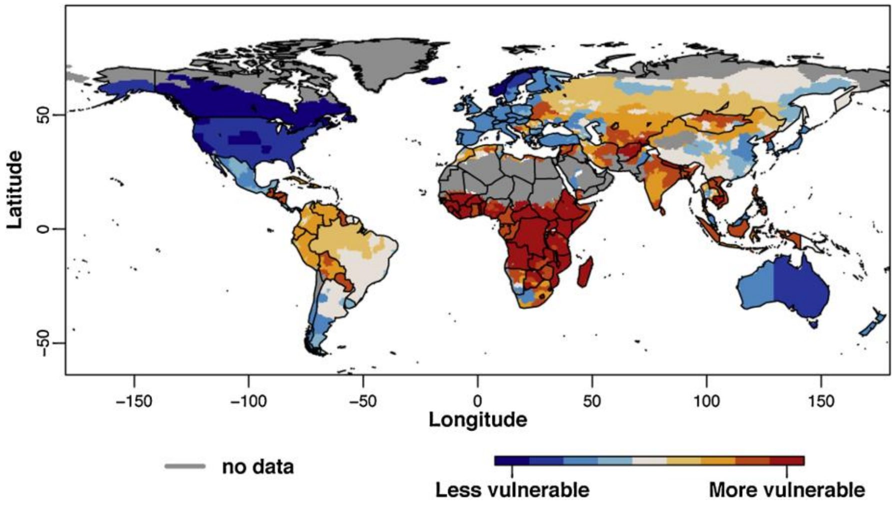


(c)

Figure 2. Global map of drought (a) hazard, (b) vulnerability, and (c) risk

Source: Carrão et al. (2016)

Despite its tropical climate, Southeast Asia has experienced several significant drought events in recent decades, often linked to the El Niño phenomenon (UNESCAP, 2020). At present, Southeast Asia faces an annual median probability of severe meteorological drought of around 4%, as defined by SPEI of less than −2 (Asian Development Bank (ADB), 2021). The duration and timing of droughts in Southeast Asia are critical factors in understanding their impact. Droughts in the region often last for several weeks to months, with the periods varying depending on the country, but typically occurring during the dry season, from March to May (Le et al., 2019; Salvacion, 2021; Suroso et al., 2021).

Phan-Van et al. (2022) examine drought characteristics specifically in Southeast Asia from 1960 to 2019, focusing on the frequency (DF), duration (DD), and severity (DS) across moderate, severe, and extreme drought categories based on the SPEI drought index. A drought spell (or a drought event) is defined as a period of consecutive drought months. Here, DF is defined as the number of drought spells, DD is the total drought month, and DS is the sum of SPEI values in all drought spells. Figure 3 shows moderate droughts exhibit a wider range in DF (3–8 spells per decade) compared to severe (2–4 spells) and extreme droughts (1–2 spells). Similarly, DD for moderate droughts ranges from 20–36 months per decade, while severe and extreme droughts last 10–16 and 5–10 months, respectively. In the mainland SEA regions, such as southern China, Indochina, and peninsular Malaysia, DF reaches 4–7 spells per decade, and DD exceeds 34 months. The Maritime Continent, by contrast, shows lower DF (3–5 spells) and shorter DD (20–36 months). Over 36 months, the longest DD is found in Thailand, northern Borneo, and Sumatra.

Overall, droughts on the mainland SEA are more frequent, prolonged, and severe than on the Maritime Continent, with the highest DS observed in Thailand, Laos, and the river deltas of Vietnam. Severe and extreme droughts follow similar spatial patterns to moderate droughts but with lower magnitudes, especially in the extreme category. These results highlight significant regional variability in drought conditions, with the mainland facing more intense drought impacts compared to the maritime regions.

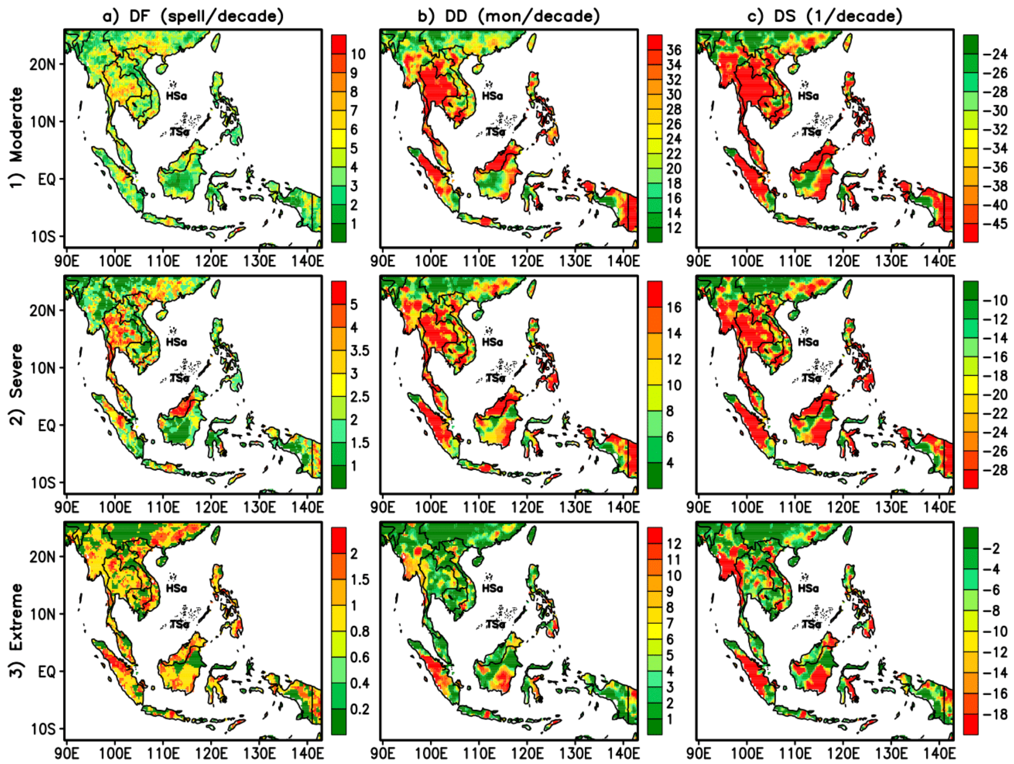


Figure 3. Climatological drought characteristics over SEA (averaged over 1960–2019): (a) DF (spells/decade), (b) DD (month/decade), and (c) DS (1/decade) for drought levels of 1) moderate, 2) severe, and 3) extreme.

Source: Phan-Van et al. (2022)

One of the most disastrous droughts of the century affecting the Southeast Asia region was the 2015 drought. The event led to widespread crop failures in Thailand, Indonesia, Cambodia, Myanmar, Malaysia, the Philippines, and Vietnam, with estimated economic losses exceeding USD 1.4 billion. In Cambodia alone, the drought affected almost 250,000 hectares of cropland and destroyed over 40,000 hectares of rice (UNESCAP, 2020).

An observation of the SPEI from the SPEIbase v.2.9 dataset (Reig-Gracia & Latorre Garcés, 2023) using Google Earth Engine (GEE) reveals that many areas in Southeast Asia experienced meteorological drought in late 2014 (Figure 4). Moderately dry conditions were observed in parts of Thailand, Lao PDR, Vietnam, the Philippines, and Indonesia (including the southwestern part of Borneo, the western part of Java, Papua, and East Nusa Tenggara). In contrast, extremely dry conditions were identified in Myanmar and Papua, Indonesia.

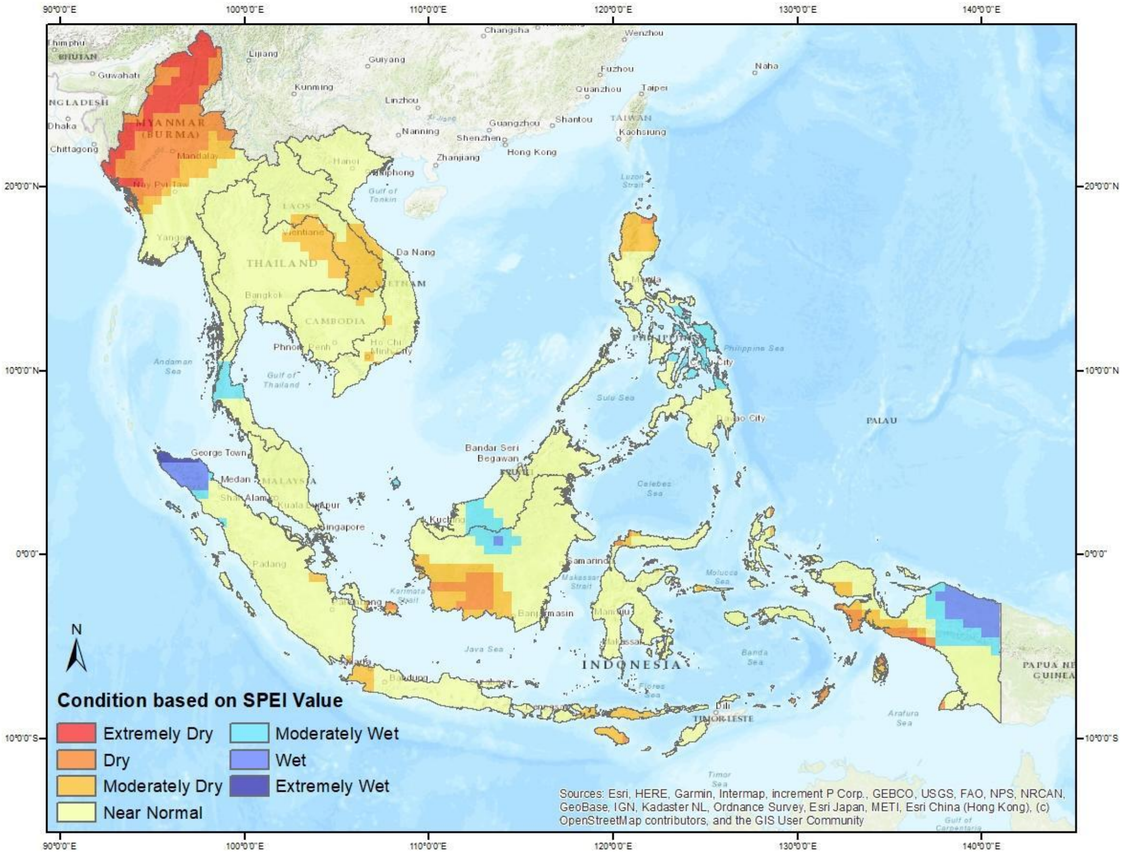


Figure 4. Southeast Asia drought condition based on 3-Month SPEI Value from December 2014 to February 2015, using data from SPEIbase v.2.9.

Source: Begueria et al. (2023)

In some parts of the region, the lack of an effective early warning system has further compounded droughts' impact. While some countries, like Indonesia and the Philippines, have developed more sophisticated monitoring and warning systems, others still struggle with timely and accurate predictions (BMKG, n.d.; GSMA, 2022). This lack of preparedness can lead to delayed responses, increasing the vulnerability of affected communities.

3.1. Drought in Cambodia

Cambodia experiences generally high temperatures and distinct seasonal rainfall patterns. The country's yearly temperature averages between 25°C and 27°C, peaking at 38°C in April and dipping to 17°C in January. Over the past decades, temperatures have risen by about 0.18°C every ten years. Rainfall distribution varies greatly, with the central lowlands receiving around 1,400 mm annually; the Cardamom Mountains and coastal regions can see up to 4,000 mm (World Bank Group & Asian Development Bank, 2021). In the eastern plains, rainfall typically ranges from 2,000 to 2,600 mm annually. The number of "hot days" has increased by 46 days per year, with about 64 days annually surpassing 35°C (USAID, 2019). Droughts remain a persistent challenge, with a 4% annual chance of severe drought. The provinces of Phnom Penh, Svay Rieng, Prey Veng, and Pailin are particularly the most vulnerable provinces to drought in Cambodia, with more than 30% of their farmland affected by severe drought conditions every 5-6 years (The World Bank Group, 2023).

Cambodia's hydrological system is largely influenced by the Mekong River, Tonle Sap Lake, and their connected streams. These water bodies are essential to the country's natural environment and economy (Chua et al., 2021; Tiwari et al., 2023). The river's flow is highly seasonal, with water levels rising during the wet season from May to October, driven by the monsoon rains. However, changes in rainfall patterns, dam construction, and deforestation pose significant threats to the river’s and lake's hydrology and the livelihoods of communities depending on it (Heng et al., 2021; Oeurng et al., 2019).

Cambodia has faced several major drought events over the past two decades, deeply impacting its agricultural sector and rural communities. In 2001-2005, a series of severe droughts affected around 2.5 million people, leading to widespread food and water shortages (Deryng et al., 2023). However, the 2015-2016 drought, driven by one of the strongest El Niño events in decades, was particularly devastating, leaving over 2.5 million people facing severe water shortages and crippling the agriculture sector (CFE-DMHA, 2017). In 2019, Cambodia was not alone in experiencing a significant drought. This event saw water levels in the Mekong and Tonle Sap drop to historic lows, impacting agricultural output and drinking water access for many rural communities in Cambodia and other Southeast Asian countries (Mekong River Commission, 2020).

The 2016 drought in Cambodia, intensified by El Niño, was the most severe in decades, causing the Mekong River to reach its lowest level in nearly a century. By March, water levels were 30-50% below average, with Koh Kong and Prey Veng provinces among the most affected. Even 60-meter deep wells faced water shortages by May, highlighting the crisis's severity. The drought led to widespread health issues, including increased cases of diarrhea, fever, and respiratory infections due to lack of clean water.

The drought's impact extended beyond health, disrupting education and livelihoods. Schools faced non-functional latrines and high student absenteeism, reaching up to 40% in some areas. Economically, farming and fishing activities were severely disrupted, forcing families to sell assets or take loans to survive. The crisis triggered increased migration, with parents leaving children behind to seek work elsewhere. Rising food and water prices exacerbated poverty, creating a multifaceted crisis that affected health, education, livelihoods, and social structures across Cambodia.

Box 1. Cambodia's Drought in 2016

3.2. Drought in Indonesia

Indonesia has a tropical climate, where zones are primarily differentiated by rainfall levels, ranging from 1,800–3,200 mm in the lowlands to 6,000 mm in some high mountain areas. Temperature varies little by season and only slightly by elevation, with average annual temperature ranging from 23°C in high mountainous areas to 28°C on the coastal plains. The mean annual temperature in Indonesia, on average, increased by 0.04℃ per decade, counted from 1985 to 2015. The El Niño Southern Oscillation strongly influences Indonesia's climate, which brings warmer, drier weather in El Niño year (USAID, 2017c).

The main cause of drought in Indonesia is the increase in temperature and rainfall deficit during a certain period, which is classified as a meteorological drought. Increased dry spells and reduced rainfall in some regions will likely increase the risk of drought and exacerbate water shortages during the dry season. For example, In 2015, the government declared 20 of the country's 34 provinces under severe drought (USAID, 2017c). To determine the drought hazard index in Indonesia, the National Disaster Management Agency (*Badan Nasional Penanggulangan Bencana/*BNPB) uses the SPEI, which is calculated based on monthly rainfall and air temperature data over a fairly long period of time (BNPB, 2023). Indonesia faces an annual median probability of severe meteorological drought of around 4%, as defined by a SPEI of less than −2 (Asian Development Bank, 2021). The arrival of the drought disaster cannot be predicted accurately, but in general, based on statistics, drought occurs approximately every four or five years. In fact, the increasing frequency of El Niño cycles can cause this phenomenon to occur more frequently.

Drought can have broad, complex impacts, lasting long after the drought ends. The wide and long-lasting impact is caused by water being a basic and vital need for all living things, which other resources cannot replace. The agricultural sector is the most affected when drought occurs in Indonesia since agriculture is one of Indonesia's main livelihood sectors. The impact on the agricultural sector is limited irrigation water, reduced planting areas, decreased land productivity, reduced crop production, and reduced farmer income. Drought can cause widespread division and conflict in the socio-economic sector, including conflicts between water users and governments.

The BNPB conducts drought risk assessments in Indonesia as part of the InaRISK project. **Figure 5** shows the results of the 2023 drought disaster risk assessment conducted by BNPB based on 2021 data.

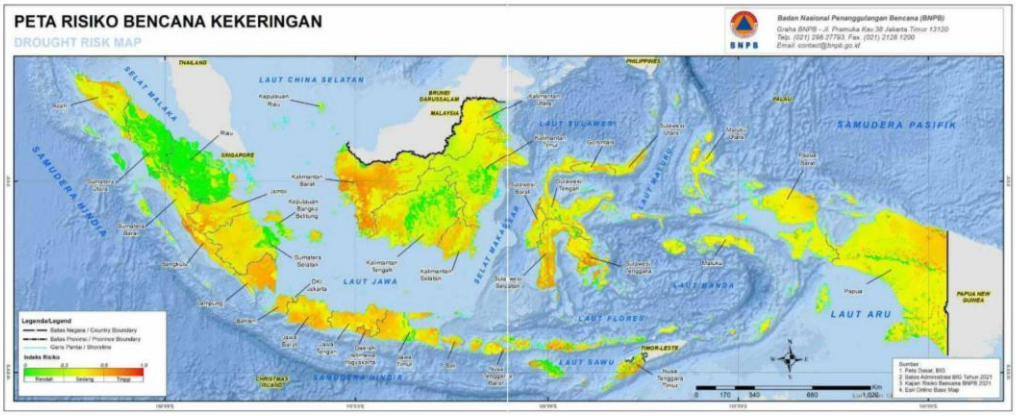


Figure 5. Drought Risk Map of Indonesia

Source: BNPB, 2023

The drought risk map in Indonesia shows that around 272,564,439 people are predicted to be affected by drought. The total risk of economic losses is estimated at USD 62.48 Billion, and the risk of damaged environment area is estimated at around 35,020,682 Ha. The province with the highest risk of economic and social losses is West Java, with an economic loss risk of USD 10.31 Billion, and there are 47,533,935 people potentially affected by drought. However, the greatest risk of environmental damage is in Papua Province, with an area of 10,716,015 Ha.

Drought in Indonesia is usually related to climate anomaly events such as El Niño and positive IOD (Indian Ocean Dipole). Because of the 43 drought events between 1884-1998, only six events were unrelated to the El Niño phenomenon in the Pacific Ocean (Irawan, 2003). According to reports from D'Arrigo and Smerdon (2008), D'Arrigo and Wilson (2008), and Field et al. (2009), positive IOD, which is a regional climate phenomenon in the Indian

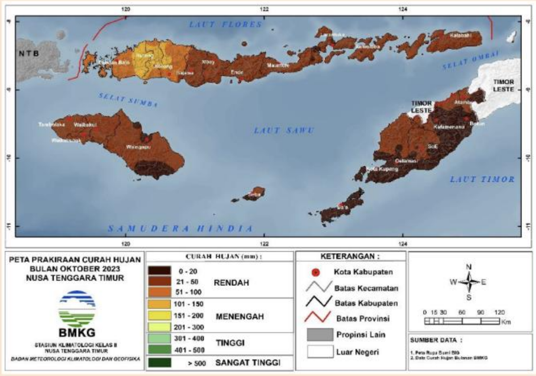
Ocean, also influences drought in Indonesia. El Niño and positive IOD events result in reduced cloud production and rain over Indonesia due to the decreasing sea surface temperature in Indonesia and its surroundings. In Q3 2023, El Niño occurred at a moderate level with a positive IOD index, causing parts of Indonesia to experience prolonged meteorological drought during the dry season. As a result, in August 2023, 23,451 hectares of rice fields were affected by drought and 6,964 hectares experienced crop failure.

BNPB data reveals that Indonesia has experienced significant fluctuations in the number of drought cases. In 2013, there were 66 reported drought cases, but this number dropped drastically to just 7 cases in 2014 and 2015. Interestingly, no drought cases were reported in 2016. However, the number rose again in 2017 with 19 cases, followed by a sharp increase in 2018 with 130 cases. This upward trend continued in 2019 with 123 cases, though it significantly decreased in 2020 to 26 cases, further dropping to 15 cases in 2021 and only 4 cases in 2022. Yet, in 2023, the number of drought cases surged dramatically to 174, marking the highest figure in the past decade.

An analysis of this data indicates that while there have been significant periods of reduction in drought cases, the long-term trend shows high uncertainty. The large spikes in 2018 and 2023 may suggest that Indonesia remains vulnerable to extreme droughts, potentially influenced by climate variability, weather phenomena such as El Niño, and global climate change. Although certain years, such as 2016 and 2022, saw very low numbers of drought cases, this does not imply a permanent reduction in drought risk. Instead, the dramatic surges in certain years reveal that drought patterns in Indonesia are difficult to predict and may intensify due to climate change. More broadly, these fluctuations signal the challenges in mitigating and adapting to climate change in Indonesia. The inability to accurately predict droughts could seriously affect agriculture, water availability, and community welfare, particularly in regions dependent on rainfall. Increased droughts in the future risk exacerbating food insecurity, affecting agricultural production, and prompting population migration due to limited water resources.

In **2023**, the province of *Nusa Tenggara Timur* (NTT), Indonesia was subjected to an exceptional drought that commenced in October and persisted until November, resulting in significant adverse impacts on the region. Indonesian Meteorology, Climatology, and Geophysics Agency (BMKG) issued a drought alert in October 2023, indicating an elevated risk of prolonged dry conditions. In response to the gravity of the situation, the Governor of NTT promptly issued an emergency alert status for drought and forest fires through Decree of the Governor of NTT.

InaRISK BNPB revealed that the NTT province has a disaster risk index of 132.81, indicating a moderate level of disaster risk according to BNPB's classification. The province is particularly susceptible to prolonged droughts, which present a considerable threat to the agricultural sector, which plays a pivotal role in NTT's economy. The recurring droughts not only endanger the livelihoods of farmers but also jeopardize the region's food security and economic stability.



Rainfall Forecast Map for October 2023, NTT
(BMKG, 2023)

Data from the Central Statistics Agency (BPS) indicate that approximately 32.000 individuals were directly affected by this drought event. The effects of the drought were particularly devastating in NTT due to the region's heavy reliance on agriculture. Nearly half the population (49,4%) is employed in the agriculture, forestry, and fisheries industries, which renders the region especially vulnerable to the prolonged absence of rainfall, which is critical for sustaining both crops and livelihoods.

Adequate rainfall is a fundamental requirement for agricultural production in NTT. The absence of precipitation during the drought period resulted in widespread crop failures. The consequences of these failures were twofold: firstly, there was a reduction in the availability of food for local consumption, and secondly, the incomes of farmers were severely diminished, a consequence of the fact that many of them are smallholders with limited financial reserves.

Box 2. Exceptional Drought in NTT Province, Indonesia in 2023

3.3. Drought in Malaysia

Malaysia's climate condition is characterised by a mean annual temperature of 25.4°C, with minimal seasonal variation. The monthly average temperature fluctuates slightly, ranging from 24.9°C in January to 25.9°C in May, with April, May, and June being the hottest months of the year based on climatological data from 1991 to 2020 (The World Bank & Asian Development Bank, 2021). Over the decades from 1969 to 2015, Malaysia has experienced a gradual increase in temperatures. Specifically, the surface mean temperature has risen by approximately 0.13°C to 0.24°C per decade. In comparison, the surface maximum temperature has increased by 0.17°C to 0.23°C per decade, and the surface minimum temperature by 0.19°C to 0.30°C per decade (Ministry of Energy, Science, Technology, Environment, and Climate Change Malaysia, 2018). Malaysia has two monsoon seasons: the Southwest Monsoon from April to

September and the Northeast Monsoon from October to March (The World Bank & Asian Development Bank, 2021).

Malaysia's climate also features substantial annual precipitation, with a mean of 3,085.5 mm/year. The average monthly precipitation remains fairly constant, ranging from around 200 mm in the drier months of June and July to about 350 mm during the wetter months of November and December (The World Bank & Asian Development Bank, 2021). However, despite the high overall rainfall, Malaysia is increasingly vulnerable to droughts. Currently, the country faces an annual median probability of severe meteorological drought—defined by SPEI of less than −2 — around 4%. Dry spells with five to ten years of return period, which can result in up to a 36.3% reduction in rainfall, are likely to occur with greater frequency. These droughts have significant economic impacts, with average annual losses estimated at USD 4,991.2 million, or approximately 1.5% of the country's GDP.

Two primary types of drought affect Malaysia: meteorological drought, which is usually associated with a precipitation deficit, and hydrological drought, which is typically linked to a deficit in surface and subsurface water flow, potentially originating from the region's wider river basins. Drought events in Malaysia are largely driven by El Niño phenomena, which disrupt normal weather patterns in the region. One of the earliest recorded droughts occurred in 1997-1998, coinciding with a strong El Niño event. This drought caused severe water shortages, especially in the Klang Valley, leading to widespread water rationing and agricultural disruptions. The 1997-1998 drought was considered one of the worst on record, with agricultural losses reaching billions of Malaysian Ringgit. The years 2002, 2014, and 2016-2018 also mark the most critical drought years in Malaysia, when more than 48% of the basin's total area was affected by hydrological drought (Hasan et al., 2021). The frequency and intensity of these droughts have raised concerns about Malaysia's vulnerability to climate change and the increasing variability of rainfall patterns. Efforts to address the impacts of drought have led to the implementation of improved water resource management and early warning systems. However, the recurring nature of these events underscores the need for long-term climate adaptation strategies, particularly in managing water resources and enhancing agricultural resilience.

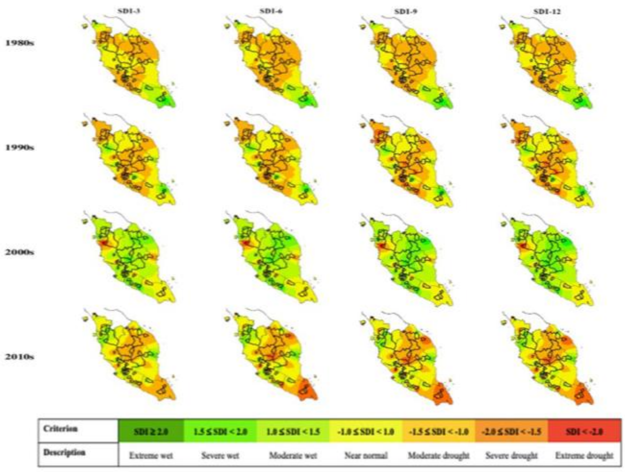


Figure 6. Spatial and temporal distribution of SDI (Streamflow Drought Index) in Malaysia by 3, 6, 9 and 12 months for 10-year intervals

Source: Hasan et al. (2021)

An example of the severe impacts of drought in Malaysia is the **2014-2016 drought**, which affected various parts of the country, including the states of Selangor and Johor (MetMalaysia, 2017). This drought led to critically low levels in reservoirs and forced the government to impose water rationing for millions of residents. During this period, reservoirs reached critically low levels, leading to water rationing and disruptions in water supply to millions of residents.

The agricultural sector was also hit hard, with reduced crop yields and economic losses for farmers. The severe drought affected 8,000 paddy farmers and caused USD 22 million in crop losses (Tan et al., 2017). This event highlighted the increasing vulnerability of Malaysia to climate variability, particularly as temperatures continue to rise and rainfall patterns become more erratic. In 2016, the drought also linked to El Niño, caused prolonged dry spells across Peninsular Malaysia, particularly in the northern states of Kedah and Perlis, disrupting water supply and agricultural activities. These disasters have had massive impacts on agriculture, aquaculture, freshwater supply, and the industrial sectors in the Kelantan River Basin.

Box 3. The Impacts of the 2014-2016 Drought in Malaysia

3.4. Drought in Myanmar

Myanmar's climate exhibits significant regional variations in temperature. Average temperatures range from 32°C in the coastal and delta areas to around 21°C in the northern lowlands, with even cooler temperatures in the mountainous regions. The hottest period typically occurs from March to April, just before the onset of the monsoon rains. Over recent decades, there has been a noticeable increase in temperatures across the country. The temperature has risen by 0.14°C per decade along the coast and by 0.35°C per decade in the interior, with the most significant increases observed in the central dry zone, where drought conditions are already severe (USAID, 2017a). These rising temperatures are exacerbating the already challenging climate in these areas, leading to more frequent and intense heat waves.

Myanmar's rainfall patterns vary similarly, with mean annual precipitation ranging from 2,500 to 5,500 millimetres (mm). The highest rainfall amounts are recorded in coastal mountains and northern and eastern regions. Conversely, the central dry zone, which is shielded from the direct effects of the southwest monsoon, receives significantly less rainfall, typically between 500 and 1,000 mm per year. This area is particularly vulnerable to water scarcity and drought. Despite this variability, there has been an increase in annual total precipitation by 157 mm per decade along the coast and 37 mm per decade inland (USAID, 2017a). However, this overall increase in rainfall does not alleviate the drought risk in the dry zone, where rainfall remains unpredictable and insufficient for agricultural needs.

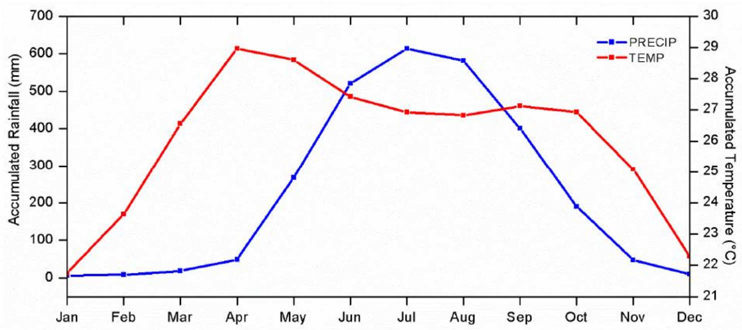


Figure 7. Annual cycle of rainfall in mm (blue) and temperature in °C (red) averaged from 1986 to 2015.

Source: Sein et al. (2021)

The central dry zone of Myanmar is especially prone to drought, with a higher hazard level compared to other regions, such as the Bago Region and the eastern mountain ranges. The dry zone's vulnerability is due to its low rainfall and high temperatures, which create challenging conditions for agriculture and water resources. While the hazard level is lower in other regions, the Yangon and Tanintharyi Regions also face significant drought risks (Ministry of Environmental Conservation and Forestry, 2012).

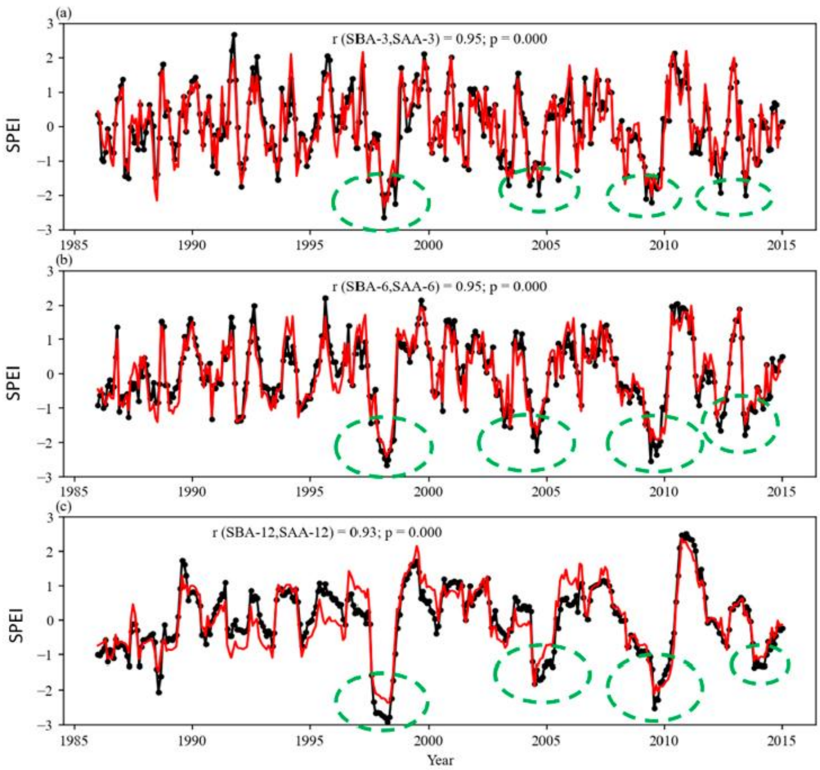


Figure 8. Average of SPEI from all stations (black line) and that based on area average of climatic parameters (red line) from 1986 to 2015 over Myanmar at the time scale 3, 6 and 12-months

Source: Sein et al. (2021)

ENSO (El Niño Southern Oscillation) and IOD influence droughts in Myanmar (Sein et al., 2021). ENSO had a significant positive correlation with droughts, especially in the coastal deltaic region from August-October. The precipitation and temperature anomalies happened during the drought from 1986 to 1999, including notable drought years like 1986-1989 and 1998, which were contrasted with wetter years after 2000. El Niño (2001-2003) and La Niña events (2010-2013) also influenced rainfall and temperature, impacting crops' water supply and heat stress. In 1998, 2005, 2010, and 2015, there was an extreme drought recorded in Myanmar at the time scale of three, six, and 12 months, with the SPEI index below -2.

One notable case of severe drought in Myanmar occurred in 2010, when the central dry zone experienced one of the worst droughts in recent history (Myanmar DMH, 2011). This event led to widespread crop failures, particularly in areas dependent on rain-fed agriculture, and had severe economic impacts on rural communities. The drought also highlighted the need for improved water management and drought mitigation strategies in Myanmar's most vulnerable regions.

The 2010 drought in Myanmar's central dry zone caused significant hardship, with vast areas of farmland left barren due to the lack of water. According to the Myanmar DMH (2011), agricultural production dropped drastically, particularly for staple crops like rice and pulses, which are heavily reliant on seasonal rainfall. Farmers in the region reported crop losses of up to 70%, leading to food shortages and forcing many households to rely on government aid and food assistance. In addition to agricultural impacts, livestock herders faced difficulties as water sources dried up, leading to a decline in animal health and productivity. The economic toll of the 2010 drought was also severe. A report by the Asian Development Bank (ADB, 2011) estimated that the drought led to a 5-10% reduction in GDP for the agricultural sector that year. The crisis further exacerbated poverty in rural

communities, where agriculture is the primary livelihood. Many farmers were forced to take on debt to survive, increasing financial instability in already vulnerable populations.

The 2010 drought underscored the urgent need for improved drought resilience and water management strategies in Myanmar. This included the development of better irrigation infrastructure and early warning systems to help farmers prepare for future droughts. The Myanmar government and international organizations began collaborating on drought mitigation initiatives, such as building rainwater harvesting systems and improving water storage facilities. Despite these efforts, the event served as a stark reminder of the country's vulnerability to climate change and the importance of long-term adaptation measures.

Box 4. The Case of Severe Drought in Myanmar in 2010

3.5. Drought in Lao PDR

Lao PDR is landlocked with rugged mountains and river systems, especially the Mekong River, which is critical in water availability. Lao PDR experiences a temperature gradient, with cooler temperatures (20°C) in the mountainous regions and warmer temperatures (25-27°C) in the plains. However, temperatures have been rising steadily, especially since the beginning of the 21st century. Vientiane, for example, has warmed by 1.03°C since 1900, with an average annual temperature increase of 0.05°C per year in the southern regions (The World Bank Group and The Asian Development Bank, 2021a).

The Southeast monsoon is responsible for most annual rainfall, reaching up to 3,000 millimetres in some areas. Its tropical monsoon climate has distinct wet and dry seasons, but climate change and El Niño events are causing increased rainfall variability, leading to more frequent and severe droughts. Lao PDR is highly susceptible to droughts, which have significantly impacted the country over the past five decades. Five or more major droughts occurred in 1977, with one of the most severe affecting nearly 3,5 million people. More frequently, localised droughts threaten rice production and household food security in specific provinces, including Khammuane, Savannakhet, Saravane, Champasack, Xayabury, and Vientiane (The World Bank Group, 2011).

In recent years, Lao PDR has experienced significant droughts, namely the 2010, 2015-2016, and 2019-2020 droughts. The 2010 drought severely impacted southern Laos during the normally rainy months of May to October, causing significant damage to the year's harvest and leading to extreme food shortages. This drought worsened the devastation caused by Typhoon Ketsana in late 2009, impacting about 85,000 people (CARE, 2010). Similarly, the 2015-2016 drought, exacerbated by one of the strongest El Niño events on record, drastically reduced rainfall during the wet season. This event strained water resources across the country, severely impacting the agricultural sector, particularly in the southern provinces where water levels in reservoirs and rivers, including the Mekong, dropped to critical lows (UNOCHA, 2024b). The most recent event was the drought that happened in 2019-2020, affecting not just Lao PDR but also most Southeast Asian Countries (UNOCHA, 2024a).

The 2019-2020 drought in Lao PDR was exceptionally severe, significantly impacting water levels, agriculture, and food security. By July 2019, the Mekong River had dropped seven meters below normal. In November, monitoring stations in Vientiane and Pakse recorded the lowest water levels in over 40 years.

The drought, coupled with flooding, severely affected vulnerable communities. By March 2020, an estimated 67,800 people faced food insecurity, particularly poor households and upland rice farmers. Crop damage and loss of livelihoods left many families struggling, with some requiring food assistance until the October 2020 harvest.

Box 5. The 2019-2020 Drought in Lao PDR

3.6. Drought in Philippines

Average annual temperatures in the Philippines have risen by approximately 1°C since 1970, with an average increase of 0.3°C per decade (USAID, 2017b). This warming trend is evident across the country, where temperatures generally remain high, particularly in low-lying areas like valleys and plains, averaging around 27°C throughout the year. Between 1958 and 2014, the annual average mean temperature rose significantly to 0.62°C (The World Bank Group and The Asian Development Bank, 2021c).

The Philippines experiences significant variability in annual rainfall, with an average of around 2,348 mm annually. However, this varies widely across different regions, from as low as 960 mm in Southeast Mindanao to more than 4,050 mm in Central Luzon. There was a rainfall deficit in the west-central and southeastern portions of the country (Salvacion, 2021). The average rainfall in the Philippines is around 188 mm, with minimum and maximum values of 65 mm and 522 mm, respectively. The southern part, especially the southeastern part, has a higher drought duration compared to other parts of the country.

Despite the high levels of rainfall, the Philippines is highly susceptible to periodic droughts, particularly those associated with the ENSO. El Niño events in the Philippines can reduce rainfall in some areas by 50%, thus resulting in drought (Damatac & Santos, 2016; Damatac et al., 2016). Currently, the Philippines faces an annual median probability of severe meteorological drought, defined by the SPEI of less than −2, of approximately 3%. The economic impact of these droughts is considerable, with average annual losses estimated at around USD 5,997.7 million (The World Bank Group and The Asian Development Bank, 2021c).

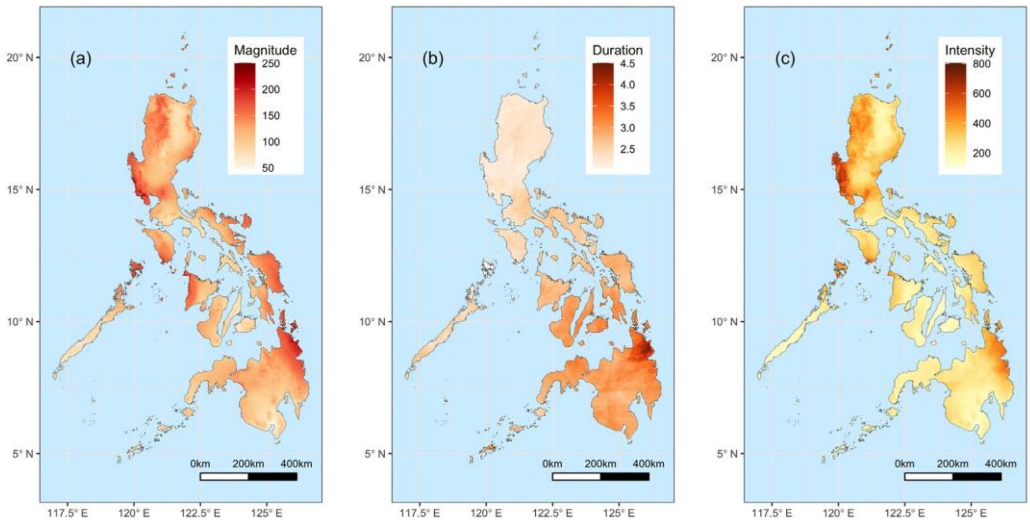


Figure 9. Spatial distribution of drought characteristics; a) magnitude (mm), b) duration (months), and c) intensity (mm/month) in the Philippines using SPI based on TerraClimate data from 1958 to 2019

Source: Salvacion (2021)

The Philippines has experienced several significant drought events throughout its history, often influenced by the ENSO. One of the most severe droughts occurred during the 2015–2016 El Niño event, devastatingly affecting the agricultural sector. Standardised Precipitation Index (SPI) assessments during the 2015–2016 El Niño highlighted extended periods of dryness across various regions, including the central and southern parts of the country. This drought resulted in widespread crop failures and reduced water availability, particularly in Mindanao and the Visayas. It impacted over 40% of the country's provinces, leading to economic losses, food insecurity, and severe water shortages (Alampay & dela Torre, 2020). Another significant drought in the Philippines was recorded during the 1997–1998 El Niño, considered one of the worst in Philippine history. This event caused agricultural losses amounting to over USD 135 million.

example of the impact of drought in Philippines is the **2015-2016** El Niño event, which led to one of the most severe droughts in recent history (NDRRMC, 2017). This drought severely affected the agricultural sector, particularly in the provinces of Mindanao. The lack of rainfall during this period led to the failure of crops such as rice and corn, which are staple foods in the country. The economic losses were substantial, with damage to agriculture alone estimated at around PHP

Box 6. The Philippines under the 2015-2016 El Niño Event

3.7. Drought in Thailand

Thailand's weather is shaped by two distinct monsoon seasons. The southwest monsoon, beginning in May, ushers in warm, moisture-laden air from the Indian Ocean, resulting in substantial rainfall across the country, particularly in mountainous regions. This effect is amplified by the Inter-Tropical Convergence Zone (ITCZ) from May to October and tropical cyclones that contribute significant precipitation. In contrast, the northeast monsoon, which starts in October, brings cooler, drier air from Chinese anticyclones, primarily affecting Thailand's northern and northeastern parts. The southern regions, however, experienced milder weather and increased rainfall along the eastern coast during this period (The World Bank Group and The Asian Development Bank, 2021b).

The country's diverse topography and monsoon influences cause varied rainfall patterns, with annual precipitation ranging from 1,200 to 4,500 mm. Leeward areas receive less rainfall, while windward regions experience higher totals (The World Bank Group, n.d.). Temperature variations are also notable, with the north averaging 26.3°C and the southern and coastal areas slightly warmer at 27.5°C, which has risen from the annual temperature in the 1950s for about 0.8°C per century (The World Bank Group and The Asian Development Bank, 2021b).

Thailand experiences recurrent drought events with varying intensity across different regions. The northeastern region, known as Isan, is particularly vulnerable to drought conditions. According to Amnuaylojaroen and Chanvichit (2019), drought frequency has increased in recent decades, with severe events occurring approximately every 3-5 years. Drought intensity and duration vary across Thailand's regions. Prabnakorn et al. (2018) observed that the northeastern and central regions are more prone to severe and prolonged droughts compared to the southern region, which typically experiences shorter, less intense dry spells.

In the 2000s, Thailand faced significant droughts that heavily impacted agriculture and water resources. The 2004-2005 drought particularly affected the northeastern region, leading to significant agricultural damage. Another severe drought occurred in 2007-2008, impacting water resources and agricultural production across multiple regions (Suwanlee et al., 2023). Thailand’s 2012-2013 drought significantly impacted multiple provinces, particularly in the northeastern region. Research indicates that the drought affected at least five provinces, including Nakhon Ratchasima, Buriram, Surin, Si Sa Ket, and Kalasin, with varying degrees of severity and consequences for agriculture (Thailand Development Research Institute, 2022). The 2015-2016 drought, one of the most severe in recent history, was linked to a strong El Niño event (Kaewthongrach et al., 2019). It affected several regions, causing widespread water shortages and crop failures. The decade ended with the 2019-2020 drought, considered the worst in four decades, severely impacting the Mekong River basin and leading to major agricultural losses, especially sugar cane (Babel et al., 2024; Bangkok Post Public Company, 2020).

The 2019-2020 drought in Thailand was one of the most severe in recent history, significantly impacting agriculture, water resources, and the economy. This drought, exacerbated by the El Niño weather pattern, affected over 41 provinces and was considered the worst in four decades.

The agricultural sector bore the brunt of the drought's impact, with rice production severely affected. The drought also had far-reaching economic consequences, with the US Office of Agricultural Affair estimating economic losses of

Box 7. Thailand’s 2019-2020 Drought and It’s Impact on Agricultural Sector

3.8. Drought in Vietnam

Vietnam has a total area of 331,212 km^2, extending from 8.2N – 23.5N and 101.1 E – 110.3 E (M.-H. Le et al., 2020). It is located in a tropical monsoon region with a high annual average temperature of approximately 24°C, a high rainfall rate of about 1,500 mm/year, and a high average annual humidity, above 80% (Liu et al., 2022). Vietnam has two distinct seasons: a rainy season that typically lasts from May to October, followed by a dry season from November to April, though the duration may vary across regions. About 65 to 75% of the total rainfall occurs in the rainy season, while there is no rain in many months in the dry season, combined with a high temperature around the year, reaching 26.70 C on average (Le et al., 2016). Located within the Southeast Asian typhoon belt, Vietnam experiences high frequencies of storms and heavy rainfall.

Vietnam's hydrology is significantly shaped by its extensive river systems, particularly the Mekong River, which flows through the country and supports diverse ecosystems and human activities. The Mekong River Delta of Vietnam (MDV) is in southwestern Vietnam (Figure 10). This delta includes 13 provinces in South Vietnam (Nghia et al., 2024). It is a vital agricultural region, providing water for rice cultivation and aquaculture, and it is home to millions of people who rely on its resources for their livelihoods.

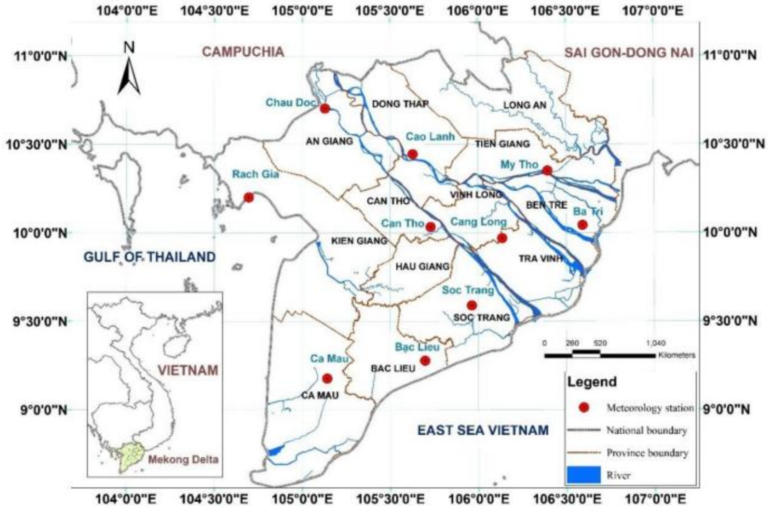


Figure 10. Map of the Vietnamese Mekong Delta

Source: Quang et al. (2021)

Despite having high annual rainfall, drought became Vietnam's third-ranked most frequent and costly disaster (Le et al., 2016; Nguyen & Shaw, 2011; Tsegai & Ardakanian, 2015). As the area that is considered to be the most influenced by climatic conditions in Vietnam, MDV becomes crucial in the country's drought assessment. It is also combined with the region's dependence on the MDV, specifically for the agricultural sector, which made this area more susceptible to drought compared to other areas. MDV has historically experienced significant droughts in 2015–2016 and 2019–2020 (Nghia et al., 2024).

According to Nguyen & Shaw (2011), Vietnam has faced several significant droughts affecting various regions from 1976 to 2005. In **1976**, a drought impacted the northern and north-central regions, followed by droughts in **1982** in the Mekong Delta, **1983** in central and southern Vietnam, **1992-1993** in the Mekong River Delta, **1994-1995** in Dak Lak province, **1995-1996** in northern regions, **1997-1998** in almost all parts of the country, **1998** in the south-central coastal area, **1999** in various regions, and **2002-2005** in the south-central coastal region. The longest El Niño-induced drought occurred from late **2015**, with significant impacts noted in **2015-2016** and **2019-2020**.

Based on the meteorological drought from 1989 to 2018, which was determined by Le et al. (2020) using the SPEI value, there is a north-south contrast in drought frequency and severity in Vietnam (Figure 11). The southern part of Vietnam, which includes the MDV area, has more frequent and severe drought compared to central and northern areas. This finding aligns with their climatology, which is wetting in the northern region and drying in the southern region.

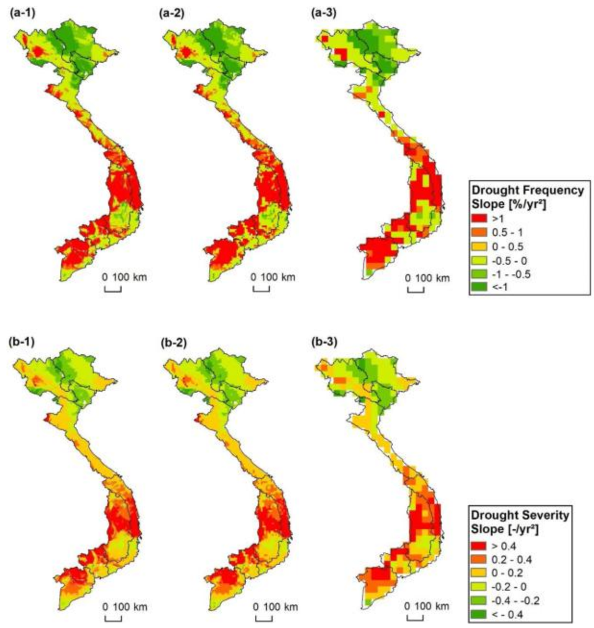
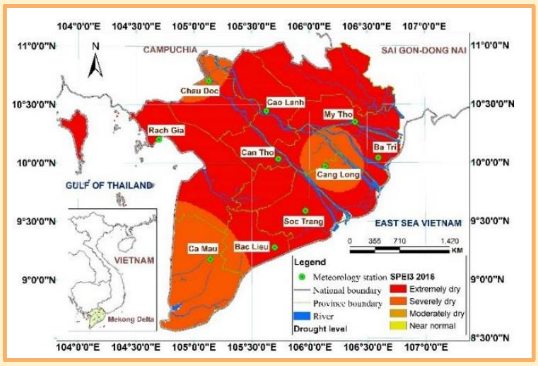


Figure 11. Drought frequency (upper) and severity (lower) based on SPEI during 1989-2018 in Vietnam in different spatial resolutions (1-, 9-, 36-km)

Source: Le et al. (2020)

Among all of the drought events, the drought in 2015–2016 became the most severely affecting drought in Vietnam. More than 83% of the country has been affected by drought since the middle of 2015. As a result, an estimated 2 million people were affected (UNDP Vietnam, 2016). It is recorded that this drought period caused 10,000 ha to stop producing crops in Khanhhoa province, Vietnam (Le et al., 2016). This drought also affected the MDV area, contributing 50% of the country's rice production and 95% of rice exports (World Bank, 2022).



The value of 3-Month SPEI in most MDV area

Box 8. The 2015-2016 Drought in Vietnam

4. Drought Management and Policies in SEA Countries

According to the historical drought occurrence records, every country in Southeast Asia has experienced drought at varying intensities and durations. The impacts are widespread, affecting agriculture, water supply, and ecosystems. These recurring challenges highlight the region's vulnerability and the pressing need for long-term strategies to manage and mitigate drought risks. In response, both national and regional governments have recognized the importance of developing drought management frameworks and policies. These may include the establishment of three key drought management pillars: Drought Monitoring and Early Warning Systems (DEWS); drought risk and impact assessments; and drought risk mitigation, preparedness, and response.

At the regional level, initiatives such as transboundary water management also help to foster collaboration among neighboring countries, especially in shared river basins like the Mekong, where cooperation is essential to manage water resources during dry periods. Countries such as Cambodia, Laos, Thailand, and Vietnam share critical water resources, necessitating coordinated efforts to mitigate drought impacts. This issue led to the establishment of regional organisations such as Mekong River Commission (MRC).

MRC facilitates transboundary drought management in the Mekong region through Articles 5, 6, and 26 of the 1995 Mekong Agreement (Mekong River Commission, 1995). Article 5 emphasises the need for reasonable and equitable water use within the Mekong River Basin and its tributaries. Article 6 mandates cooperation among member countries to maintain adequate flows in the Mekong River's mainstream. Article 26 assigns the Joint Committee responsible for developing water utilisation and diversion rules. These provisions ensure sufficient water availability during dry seasons while managing excess flows during the wet season, fostering sustainable and cooperative water governance in the region.

In 1999, the Mekong River Commission (MRC) established a Water Utilisation Programme (WUP) to develop a set of rules for water utilisation in the Lower Mekong Basin (LMB) mandated by Article 26 of the 1995 Mekong Agreement. This initiative led to the development of five key procedures:

1. Procedures for Data and Information Exchange and Sharing (PDIES) – 2001
2. Procedures for Water Use Monitoring (PWUM) – 2003
3. Procedures for Notification, Prior Consultation, and Agreement (PNPCA) – 2003

4. Procedures for the Maintenance of Flows on the Mainstream (PMFM) – 2006
5. Procedures for Water Quality (PWQ) – 2011

These procedures provide the framework for implementing transboundary drought management in the region (Mekong River Commission, n.d.-b).

To enable effective drought management, hydrometeorological monitoring in the Lower Mekong Basin (LMB) is carried out through several monitoring stations from projects such as the Mekong Hydrological Cycle Observing System (HYCOS) and the MRC Joint Environment Monitoring (JEM) Programme. These stations transmit near-real-time water level and rainfall data from key locations within the LMB and its tributaries at 15-minute intervals that can be accessed publicly through the MRC websites. All stations are operated and managed by the relevant provincial or national agencies of the four member countries. The MRC is working continuously to further expand the hydrometeorological network.

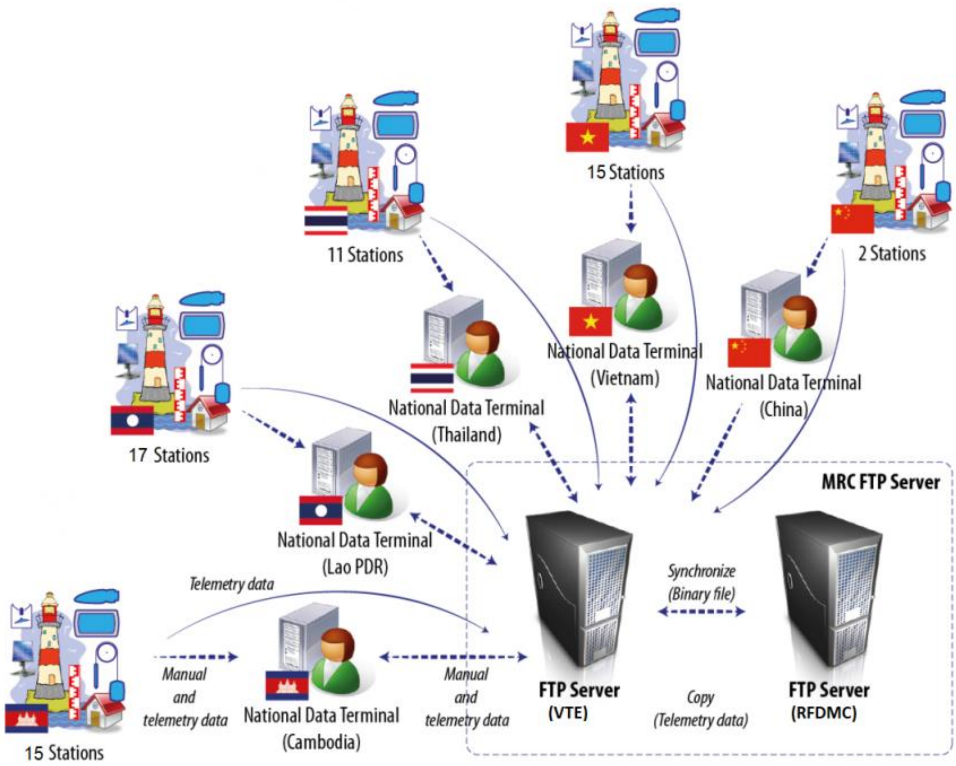


Figure 12. Mekong Hydrological Cycle Observing System (HYCOS)

Source: Mekong River Commission (n.d.-a)

The monitoring data from these hydrological monitoring stations serve as the basis for implementing the Procedures for the Maintenance of Flows on the Mainstream (PMFM) (Mekong River Commission, n.d.-b). These procedures outline the necessary interventions to enforce Article 6 of the 1995 Mekong Agreement, ensuring that mainstream flows are maintained such that :

a. They are not less than the acceptable minimum monthly natural flow during each month of the dry season
b. They enable the acceptable natural reverse flow of the Tonle Sap to take place during the wet season; and
c. They prevent average daily peak flows greater than what naturally occur on the average during the flood season

The monitoring data has been pivotal in improving stakeholders' understanding of the implementation and evaluation of interventions such as water allocation and water demand management (Mekong River Commission, 2022). Furthermore, it allows for effective planning of future interventions and strategies to adapt to the region's growing challenges of drought management.

Another notable effort in monitoring climate-related risks at the regional level is the establishment of SERVIR SEA, a decision support platform powered by satellite data and geospatial technology. Building on the success of SERVIR Mekong, this collaboration between USAID, NASA, and the Asian Disaster Preparedness Center (ADPC) aims to extend climate services across the SEA region. The initiative provides various decision-making tools addressing sectoral challenges such as air quality, flood and drought management, and land use change. One key tool, the SEA Drought Watch (SEADW), was developed in partnership with MRC and other institutions to support governments, farmers, and organisations with drought forecasting and warnings. In addition, the platform facilitates both short- and long-term drought mitigation measures. These innovative tools and approaches have been instrumental in developing the technological and institutional capabilities of stakeholders in the region.

ASEAN, as a regional governing body, has taken steps to address drought and broader disaster management across Southeast Asia. The need for an integrated regional framework for drought management was first highlighted in the Ready for the Dry Years report, a joint publication by UNESCAP and the ASEAN Secretariat. Drawing on national drought policy dialogues held in Cambodia, Lao PDR, Myanmar, and Vietnam, the report identifies key challenges and informs regional priorities. Its recommendations laid the foundation for the ASEAN Declaration on the Strengthening of Adaptation to Drought, which outlines the collective commitment of ASEAN member states to tackle the growing risks and impacts of drought in the region.

Building on this declaration, ASEAN developed the *ASEAN Regional Plan of Action for Adaptation to Drought (ARPA-AD) 2021–2025*, a strategic roadmap for regional cooperation on drought resilience. ARPA-AD consists of nine groups of action: (1)

risk, impact, and vulnerability assessment; (2) early warning system, preparedness and planning, (3) adaptation actions, and (4) response and recovery; while partnership and coordination actions are (5) strengthening coordination between ASEAN sectoral bodies, (6) partnership and collaboration with non-ASEAN partners, (7) capacity-building/enhancement, (8) data sharing and dissemination, and (9) monitoring and evaluation. The plan aims to support member states in developing comprehensive, inclusive, and adaptive drought responses while promoting coordination across sectors and borders.

Transboundary and regional efforts have enabled countries to manage drought risks better and build adaptive capacities in the face of drought. However, geopolitical distrust and tension remain significant obstacles to achieving a more integrated and effective disaster management approach (Robby et al., 2023). This is especially evident in drought-related issues, where upstream countries can wield considerable influence over water resources, potentially placing downstream states at a disadvantage. Southeast Asian countries are encouraged to conduct vulnerability assessments to inform comprehensive strategies tailored to both local contexts and transboundary challenges (MRC, 2010). Recognising that drought does not adhere to national boundaries; stakeholders can develop holistic policies that integrate best practices from multiple countries. This approach fosters resilience and ensures that transboundary communities are better prepared for drought impacts, prioritising the sustainable management of shared water resources and socio-economic stability amidst climate variability. Ultimately, effective transboundary drought management policies contribute to regional security and cooperation, reinforcing the interconnectedness of Southeast Asian nations in tackling drought-related challenges (Pham, 2015).

Beyond initiatives led by countries and regional institutions, Global partners have also played a key role in supporting these efforts. The United Nations World Food Programme (UN WFP), for example, has pioneered an anticipatory action program in partnership with the International Federation of Red Cross and Red Crescent Societies and the German Red Cross (Kabir et al., 2024). This program aims to identify critical data points, establish actionable triggers, and develop mechanisms for the early release of humanitarian funding before an emergency occurs. Focused particularly on climate-related disasters like drought, this proactive approach is reshaping how aid is delivered, enabling faster, more efficient responses that can significantly reduce human and economic losses. Anticipatory action has been implemented in many countries across Asia and the Pacific, such as Bangladesh, Nepal, Fiji, Kyrgyz Republic, and Pakistan, and is being developed in several Southeast Asian countries including the Philippines, Indonesia, Cambodia, and Lao PDR. Notably, anticipatory action protocols for agricultural drought have also been established in Lao PDR, with funding for activation provided through UN Food and Agriculture Organization (FAO)'s Anticipatory Action window under the Special Fund for Emergency and Rehabilitation Activities (SFERA), generously supported by the German Federal Foreign Office (Food and Agriculture Organization (FAO), 2023).

4.1. Cambodia

Cambodia faces significant climate-related hazards, including droughts, which have historically caused widespread impacts across its provinces. To manage drought risks, Cambodia uses a combination of satellite-based and meteorological data to monitor drought conditions. Specifically, the Ministry of Water Resources and Meteorology (MoWRAM) plays a key role in flood and drought monitoring, providing seasonal forecasts and issuing early warning. The MoWRAM has worked with the SERVIR-Mekong initiative to utilise satellite / earth observation data to improve its hydrological models. Similar initiative by WFP, Platform for Real-Time Impact and Situation Monitoring (PRISM), also uses earth observation data in conjunction with geospatial data on hazard and socioeconomic indicators to inform disaster risk reduction and social assistance programs. This is further enhanced by 'Strengthened Sesame' system, which monitors drought conditions and disseminates early warnings through mobile applications and voice messaging (United Nations Development Programme (UNDP), n.d.). This system has been integrated with tailored training for staff to improve climate forecasting and hydrological modelling. Cambodia relies on climate projection data from the Coupled Model Intercomparison Project, Phase 6 (CMIP6), foundational for global climate change projections. CMIP6 uses Shared Socioeconomic Pathways (SSPs) to represent possible societal development and policy scenarios, helping to predict future climate conditions, including the likelihood and severity of droughts. These projections are crucial for early warning systems that can help mitigate the effects of droughts on Cambodia's vulnerable sectors.

Other key actors in the drought management from the government sector include the National Committee for Disaster Management (NCDM) and Ministry of Agriculture, Fisheries and Forestry (MAFF). NCDM oversees overall disaster management and impact assessments, while MAFF plays a critical role in coordinating with the agricultural sector. It provides essential agricultural data that, when integrated with weather information, supports crop management and helps mitigate the impacts of drought. While the MoWRAM is responsible for observation, detection, and the formulation of warnings, the NCDM remains as the central agency for disseminating these warnings through its decentralized structure. Under NCDM, disaster management committees operate at the provincial, district, and commune levels. Additionally, organizations such as the Red Cross and other relevant entities are coordinated to ensure effective last-mile communication of early warning information.

Several initiatives could further enhance drought management in Cambodia. One notable effort is the Early Warning System 1294 (EWS 1294), which was established in 2017 to provide the public with advance alerts about natural disasters. Currently, the system is primarily focused on flood-related warnings. However, there are ongoing plans to expand its capabilities into a multi-hazard early warning system, which would include drought and other climate-related risks (People in Need (PIN) Cambodia, 2022). Another important initiative is the Cambodia Disaster Damage and Loss Information System (CamDi), a platform developed by NCDM with assistance of UNDP, UNDRR, LARED, OSSO, RobotSearch and Apache Software Foundation, which collects and manages data on disaster impacts across the country. Effective utilisation of these systems could significantly improve drought management by strengthening early warning capabilities and enhancing the understanding of risks and vulnerabilities across Cambodia.

In response to its climate vulnerabilities, Cambodia has developed several strategies and plans. The Royal Government of Cambodia launched the Climate Change Strategic Plan (CCCSP) in 2013, which has served as the overarching policy framework for climate change mitigation and adaptation for over ten years (National Climate Change Committee of Cambodia (NCCC), 2013). Additionally, the Updated Nationally Determined Contribution (NDC) submitted in 2020 outlines goals for reducing carbon emissions and deforestation rates by 2030 (The General Secretariat of the National Council for Sustainable Development/Ministry of Environment, the Kingdom of Cambodia, 2020). These strategies are vital for addressing the broader climate challenges, including droughts, and ensuring sustainable resource management.

Climate change, in general, was classified as a priority development issue in the 2009-2013 National Strategic Development Plans (NSDP).

Subsequent NSDPs evolved it into a cross-cutting issue, signifying its impact on all sectors. These plans were further detailed in Sector Strategic Development Plans, with a particular focus on sectors such as agriculture, forestry, and ecosystems (Ministry of Planning of Cambodia, 2019).

The Climate Change Strategic Plan (CCSP) 2014-2023 was introduced to address climate change more comprehensively. Its primary objectives included:

- Enhancing climate resilience by bolstering food, water, and energy security.
- Protecting critical ecosystems such as the Tonle Sap Lake, Mekong River, coastal areas, highlands, biodiversity, protected areas, and cultural heritage sites.
- Strengthening institutional frameworks and coordination for national and regional climate change responses.

Non-Governmental Organisations (NGOs) and Civil Society Organisations (CSOs) in Cambodia hold a significant role in supporting drought mitigation efforts. These organisations often collaborate with the government to implement community-based programmes that enhance resilience in food security, environmental conservation, and social protection. For example, UNDP, supported with funding from the Global Environment Facility-Least Developed Countries Fund, conducted the 'Weather Stations, Women Champions and Water Management: Changing the Face of Early Warning in Cambodia' project (2015-2020) to support the Royal Government of Cambodia to bridge existing gaps in institutional capacity, inter-ministerial coordination, and infrastructure (UNDP, n.d.). The project focused on enhancing the inclusion of climate change considerations in short- and long-term planning, sectoral planning, and other decision-making processes that were implemented in these strategies.

- National Groundwater Management Strategy

  Cambodia's water resources are under pressure due to climate change, land conversion for agriculture and industry, and increasing demand. The National Groundwater Management Strategy addresses these challenges by promoting sustainable groundwater use. The strategy includes recommendations for improving institutional frameworks and law enforcement, developing human resources, managing data effectively, boosting coordination and cooperation, raising public awareness, and mobilising resources. In support of this strategy, staff from the Department of Water Supply and Sanitation received specialised training to enhance their skills.

- National Drought Management Strategy

  Based on findings from a drought research study, the project developed a National Drought Management Strategy. This strategy includes recommendations on how drought models can be utilised to create an early warning system specifically designed for Cambodia.

- Drought Management Manual for practitioners

  In collaboration with DanChurchAid, Cambodia’s Drought Management Manual covers various key topics such as understanding climate variability, explaining drought-related concepts and definitions, methods for drought analysis, the use of the Standardised Precipitation Index (SPEI), risk management strategies, and includes relevant case studies.

The government's strategies, such as the CCCSP and NDC, have laid a solid foundation for climate resilience. However, the effectiveness of these interventions is sometimes limited by insufficient resources, inadequate infrastructure, and the challenges of implementing policies at the local level. Additionally, while early warning systems have improved, their reach and effectiveness in rural areas remain a concern.

Despite the progress, there are significant gaps in Cambodia's drought management framework. The country needs enhanced technical and financial support to improve monitoring and early warning systems, particularly in rural and high-risk areas. There is also an urgency for stronger infrastructure and capacity-building initiatives to ensure that government policies and NGO programmes can be effectively implemented and sustained. Ultimately, international cooperation and investment in technology transfer will be crucial in addressing these gaps and building a more resilient Cambodia through drought hazards.

4.2. Indonesia

The Meteorological, Geophysical, and Climatological Agency (*Badan Meteorologi, Geofisika, dan Klimatologi/*BMKG) of Indonesia has developed the Climate Early Warning System (CEWS) as mandated by Law Number 31 of 2019. The system is designed to reduce the impacts of climate extremes by providing early warnings for relevant sectors. The information monitored by CEWS includes: (1) meteorological drought potential (dry season onset, consecutive dry days (CDD), 1-month SPI analysis), (2) high amount of rainfall potential, and (3) global climate anomaly (e.g., El Niño, La Niña). This system enables the agency to issue early warnings for disasters like floods, landslides, and droughts, allowing communities, authorities, and disaster management agencies to take proactive measures to reduce risks (Utami & Nurhayati, n.d.). For example, the National Committee of Water and River Basin Management consists of the Directorate General for Water Resources, National Meteorology Service, Directorate of Groundwater and Earth, as well as relevant NGOs, use the early warning data to formulate recommendations for the policymakers at the national level on various water resources programmes, including drought.

Additionally, the Ministry of Environment and Forestry (MoEF) of Indonesia has developed tools to assess vulnerability at the village level through the Vulnerability Index Information System (*Sistem Informasi Data Indeks Kerentanan/*SIDIK). SIDIK determines the level of vulnerability in villages through the assessment of indicators that affect exposure, sensitivity, and the village's adaptive capacity. The local governments use SIDIK to develop adaptation action plans. Nationally, the data shows that about half of Indonesian villages fall under the category of medium to very high vulnerabilities.

Furthermore, various government agencies conduct sectoral vulnerability assessments in Indonesia, each employing different frameworks and methodologies. For instance, sectors like water resources, agriculture, and coastal areas have detailed vulnerability assessments, often incorporating climate models and projections. These assessments aim to identify how sectors will be affected by climate change and natural disasters. However, using different frameworks and methodologies across sectors can result in inconsistent data, making it challenging to integrate findings into a unified local or national adaptation strategy.

Indonesia has taken various measures to alleviate the impact of drought. In the agriculture sector, short-term mitigation efforts include:

- Planting calendar: the use of a planting calendar (*kalender tanam*) provides guidance on optimal planting times based on current climate conditions.
- Irrigation management: techniques such as water rationing and the adoption of sprinkler systems are used to optimise water use.
- Drought-resistant seeds: the governments distribute water-resilient crop seeds for farmers affected by drought.
- Water pumps: the provision of water pumps to access groundwater as a temporary solution to drought.

Long-term strategies in the agriculture sector include:

- Construction of reservoirs and dams: large-scale reservoirs and dams are built to increase water storage capacity.
- Groundwater wells: drilling and maintaining groundwater wells provide additional water sources for agricultural and domestic use.
- Development of drought-tolerant crops: research and development of drought-resistant crop varieties to provide farmers crop alternatives during drought.
- Public awareness and capacity building: training for farmers that aims to improve water management practices and resilience to drought conditions.

In the water resource sector, emergency water supplies are distributed through water trucks and tanks, especially to fulfil domestic water needs during drought events. In addition, weather modification technology (*Teknologi Modifikasi Cuaca*/TMC) is being used more often to increase rainfall in drought-affected and fire-prone areas and to fill water reservoirs in preparation for a drought. TMC proved to be effective in mitigating drought-induced forest fires, as they could increase rainfall by up to 19% compared to the historical average in a region (Tukiyat et al., 2022). During the 2023 El Niño event, TMC helped Indonesia reduce 80-90% forest fire occurrence (Antara News, 2024).

Most of the disaster events in Indonesia (>95%) are hydrometeorological in nature, meaning that the occurrences are related to climate change conditions. Consequently, efforts have been made in the past years to converge climate change adaptation with disaster risk reduction measures. The Government of Indonesia (GoI), through the Ministry of National Development Planning, has enacted the National Action Plan for Adaptation of Climate Change (*Rencana Aksi Nasional untuk Adaptasi Perubahan Iklim/*RAN-API) that tries to address the impact of climate change and the disasters associated with it. The action plans prioritised four sectors, namely:

1. Water

The main strategy for the water sector is to improve the management of water resources to ensure that the water supply meets the demand for clean water and to prevent the damage caused by water-related climate disasters. This translates to action plans on the construction of infrastructure (e.g., dam, retention basin, rainwater harvesting facility, infiltration well), use of water management technologies (e.g., weather modification and aquifer storage, capacity building (e.g., training and campaigns), and improving governance through policy and legislation (e.g., technical standards, protected areas, masterplan development).

The government also strongly emphasises Integrated Water Resources Management (IWRM). The legal and institutional framework for IWRM in Indonesia is already advanced (ADB, 2016). Law Number 17 of 2019 provides the ground for sustainable water resource management as the law mandates the protection and conservation of water catchment areas, watersheds, and groundwater. The law's key objectives are to establish state control over water resources, ensure water accessibility as a human right, and encourage community involvement in water resource management. Each river basin territory, or *Balai Wilayah Sungai* (BWS), is assigned to a river basin organisation that is responsible for the basin management. This allows the formulation of a basin plan that involves many stakeholders, resulting in less potential for conflicts, better planning, and improved coordination.

2. Agriculture

In the agriculture sector, RAN-API outlines action plans to ensure the sustainability of food production and livelihoods in the face of climate change. One of the primary focuses is on increasing the resilience of crops to extreme weather conditions, such as droughts, floods, and temperature shifts. This involves the development and promotion of climate-resistant crop varieties, which are more tolerant to erratic weather patterns and pests. The plan also emphasises the need for improved irrigation systems that adapt to water scarcity during dry seasons and excessive rainfall during wet periods. Techniques like rainwater harvesting, drip irrigation, and the efficient use of water resources are encouraged to make farming less vulnerable to unpredictable rainfall.

Additionally, the action plan supports sustainable farming practices to enhance soil health and reduce dependency on chemical inputs, which can further degrade the land under changing climate conditions. This includes the adoption of agroforestry, crop rotation, and organic farming methods that increase biodiversity and improve resilience against climate impacts. RAN-API also stresses the importance of capacity building for farmers, providing them with training and knowledge on climate-smart agriculture, access to weather forecasts, and tools for better farm management. The plan also promotes diversification of livelihoods for farmers, encouraging the adoption of alternative income-generating activities, such as aquaculture or livestock farming, to reduce vulnerability to crop failures caused by climate change.

3. Marine and coastal

In the marine and coastal areas sector, the RAN-API emphasises adaptation strategies to protect Indonesia's coastal ecosystems and mitigate risks associated with climate change, particularly rising sea levels and increased storm frequency. Action plans include restoring and conserving mangroves, coral reefs, and other coastal habitats that act as natural barriers against coastal erosion and flooding. These ecosystems also provide vital resources for local communities. The plan advocates for sustainable coastal zone management, integrating climate considerations into policies that govern land use and development near coastlines, as well as enhancing early warning systems for coastal hazards such as tsunamis and storm surges. Additionally, it promotes community-based adaptation initiatives, such as building sea walls, improving drainage systems, and relocating vulnerable settlements from high-risk zones.

4. Health

For the health sector, RAN-API focuses on strengthening the country's ability to cope with health risks intensified by climate change, such as heat-related illnesses, vector-borne diseases (like malaria and dengue), and water-borne diseases. Action plans include improving healthcare infrastructure, especially in climate-vulnerable areas, and ensuring that health facilities are equipped to handle emergencies and extreme weather conditions. This involves improving access to clean water and sanitation, which are critical to preventing disease outbreaks. Moreover, RAN-API calls for the development of public health early warning systems that can forecast disease outbreaks linked to climatic factors, enabling quicker responses and prevention measures. Increasing community education and awareness is also a major focus, ensuring that populations understand the health risks posed by climate change and are better prepared to adapt, such as through behaviour changes or by seeking timely medical assistance.

In Indonesia, drought is a recurring issue that extensively affects different social groups from various regions. As such, the approach to adaptation and mitigation should involve the contribution of many stakeholders. The NGO and CSO sectors have been actively involved in both adaptation and mitigation efforts to address the impacts of drought. Some of the key programmes are:

1. Water, Sanitation, and Hygiene (WASH) Programmes

As one of the most prominent issues of sustainable development, many organisations in Indonesia implement WASH projects. Notable ones include the USAID IUWASH Tangguh, a USD 44.1 million project involving the Government of Indonesia, NGOs, as well as other stakeholders. This project addresses climate-related risks, such as floods and droughts, across 38 municipalities. The programme focuses on tackling water service challenges by strengthening WASH and water resource governance and financing, increasing access to climate-resilient services, and improving resource management (USAID, 2024). Water.org, on the other hand, adopts a different approach with its microfinance initiative, WaterCredit, which offers repayable microloans to help vulnerable communities gain access to water and sanitation. Meanwhile, other programmes, such as the UNICEF WASH programme, focus more on policy advocacy and capacity building in trying to improve the political will towards behaviour change in the water and sanitation sector. Overall, the WASH sector benefits from significant efforts and attention from a wide range of organisations in Indonesia.

2. Sustainable Agriculture and Food Production Programmes

The agriculture and food production sectors are among the sectors most impacted by climate change and drought. It is especially important in Indonesia, where many regions have already experienced food security challenges and increased vulnerability to climate-related events. To address various organisations, implement these programmes related to sustainable and resilient agriculture and food production. Many of these programmes are directed to increase food security through the adoption of resilient crops. In East Flores, Yayasan KEHATI (KEHATI, 2022) and Oxfam Indonesia (Oxfam, 2023) conduct capacity building and training for local communities to drive the development of sorghum crops, which could grow in hot areas with little rainfall. Similar projects are done in Papua and Sumba, where farmers are encouraged to plant, process, and consume locally grown food such as bananas and sago to reduce reliance on rice, which is not suitable for growing in the area.

Another significant initiative addressing sustainable agriculture in Indonesia is the Horticulture Development in Dryland Areas Project (HDDAP), a EUR 129.04 million partnership between the International Fund for Agricultural Development (IFAD), the Asian Development Bank (ADB), and the Indonesian Ministry of Agriculture (IFAD, 2023). HDDAP aims to promote climate-smart agriculture practices, improve infrastructure resilience, and strengthen the capacity of smallholder dryland farmers through the introduction of drought-resistant crops, training in water conservation practices such as efficient irrigation techniques and rainwater harvesting, and promoting organic farming and agroforestry. The project extends to investment in upgrading irrigation infrastructure to ensure reliable water access in the event of water scarcity. It also aims to consolidate small-scale farmers to reap the benefits of economies of scale and form effective organisations that produce high-value crops. These efforts are expected to be beneficial in addressing challenges posed by drought and other climate-related disasters in Indonesia.

3. Disaster Risk Reduction and Livelihood Diversification Programmes

In response to the increasing frequency of climate-induced disasters, including droughts, many organisations in Indonesia are focusing on disaster risk reduction (DRR) and livelihood diversification to enhance community resilience. One of the efforts is to implement a community-based risk reduction project in which capacity-building activities are done to prepare the local community for disasters. The Indonesian Red Cross (PMI), in partnership with the American Red Cross, is implementing the Integrated Community-Based Risk Reduction Project in 100 villages across four districts in Bogor. Similarly, Wahana Visi Indonesia has reached 16,234 people over 56 districts in Indonesia to reduce vulnerabilities and minimise damages through community-based DRR.

Furthermore, efforts have been put toward diversifying the livelihood of vulnerable communities in the agriculture sector. Mercy Corps Indonesia ran economic empowerment programmes along with its climate change and disaster risk reduction programmes. One of them is MAMORA, a program that focuses on developing the resiliency of coffee farmers through digital and business literacy improvement (Mercy Corps, 2022). Indonesia's forestry policy also enables local communities to develop social forestry practices with support from NGOs and CSOs. In Bali, Kalimajari, a local NGO, implemented the Transforming the Cocoa Sector in Indonesia Through Value Addition for Smallholders (TRACTIONS) programme (Ministerie van Landbouw, n.d.). They practice cocoa agroforestry, which combines cocoa with coconut and banana. The programme also introduces livestock farming in the forest area. Similar agroforestry projects are done in many regions in Indonesia by various organisations, utilising local resources to improve sustainability while providing the local community with livelihood options.

Significant changes are observed in Indonesia through drought-related interventions and programmes done by the government and NGOs. The key outcomes and limitations are:

1. Early Warning System Development

Though still in development, the implementation of the Climate Early Warning System (CEWS) and other weather-based EWS have successfully provided early alerts, leading to proactive responses like water rationing and preparation for droughts. The data generated by CEWS is also used by multiple agencies in Indonesia, improving the decision-making process in policy development. However, limitations arise from uneven access to real-time data at local levels, limiting its full effectiveness in remote regions.

2. Mitigation and Adaptation

The development of EWS in Indonesia has enhanced forecasting and disaster preparedness, enabling better responses to droughts and other climate hazards. Technological advancement, especially in weather modification technology, has seen substantial impacts on reducing the impact of drought on forest fire occurrences. Advocacy and capacity building in the disaster reduction and sustainable agriculture sector done by various organisations has improved the conditions and mitigated some of the drought impacts. The adoption of integrated water resource management, in conjunction with the construction of water infrastructure and facilities, has improved water availability and access. The challenge lies in securing the funding to sustain these efforts, many programmes and projects are not funded by the government's budget and come from external sources, such as international aid and donations.

Despite the progress made in drought management in Indonesia, several gaps remain that hinder the effectiveness of current interventions. Areas for improvement identified are as follows:

1. Data Comprehensiveness and Accessibility

Addressing the gaps in real-time data accessibility and comprehensiveness, particularly in the development of CEWS, is crucial to ensure a timely and accurate response to drought and other climate disasters. Efforts should focus on the development of data collection and monitoring infrastructure and technology. Fortunately, the importance of addressing this gap has already been captured in Indonesia’s climate adaptation and mitigation strategy. With the right implementation, a better data collection system could be achieved. This would not only improve the effectiveness of EWS but also enable better risk and vulnerability assessment.

2. Coordination Between Agencies

Indonesia's drought management efforts are often fragmented across multiple government agencies and organisations. The lack of standardised frameworks and methodologies leads to inconsistent data collection and analysis, hindering a uniform approach to vulnerability assessments and disaster responses. Enhanced coordination between agencies and the integration of sectoral vulnerability assessments is necessary to create a comprehensive drought management framework.

3. Sustainability of Interventions

Many of Indonesia's drought mitigation programmes rely heavily on external funding and international aid. This dependence raises concerns about the long-term sustainability of these interventions if external financial support decreases. Therefore, there is a need to secure government budget allocations to maintain and scale adaptation and mitigation programmes. This can be done by leveraging innovative ways to fund, such as community-based financing and public-private partnerships.

4. Public Awareness and Capacity Building

Despite many efforts by the government and NGOs in Indonesia in regards to capacity building, there are still significant gaps in public education and local capacity to manage drought risks effectively. Many rural communities do not have access to training on water management practices, climate-resilient agriculture, and drought adaptation strategies. This is likely due to geographic and socio-cultural challenges in transferring knowledge to communities in remote areas. Expanding capacity-building programmes and ensuring they reach the most vulnerable communities is vital for increasing local resilience.

4.3. Malaysia

The Meteorological Department (MetMalaysia) and the Department of Irrigation and Drainage (DID) of Malaysia play a key role in issuing early drought warnings by utilising real-time monitoring from a network of watch stations (MESTECC Malaysia, 2018). The network uses 41 water levels and rainfall stations to provide information about real-time situations involving dam storage, river flows, and rainfall data. Early warnings are issued based on rainfall deficits over consecutive months, with alerts escalating from ‘Alert’ to ‘Emergency’ depending on SPI thresholds. DID disseminates information on water resources and provides early warnings through a web portal named *Infokemarau* to inform the public and relevant agencies to prepare them for drought events.

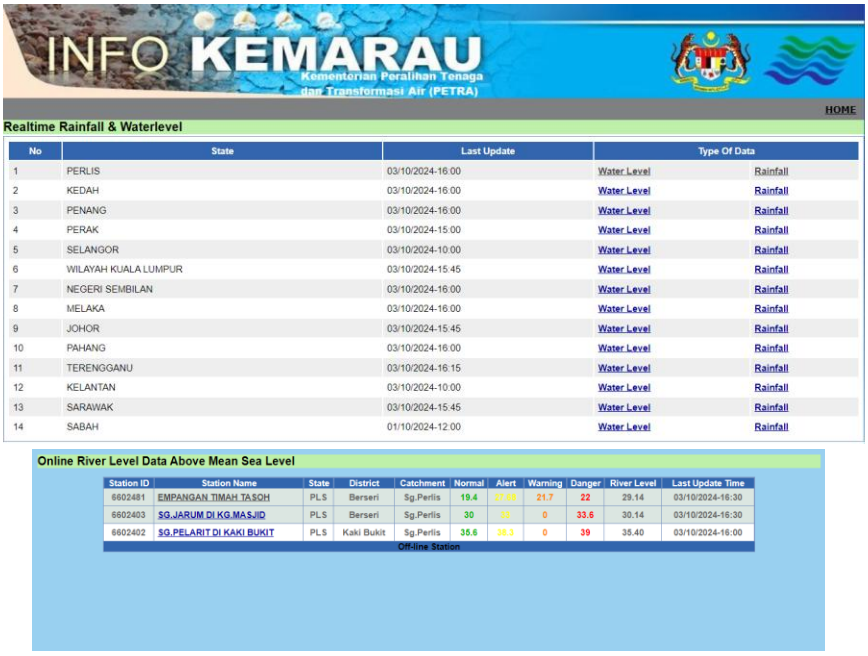


Figure 13. *Infokemarau* User Interface

The National Disaster Management Agency (NADMA) and DID play a central role in managing disaster risks, including drought hazards. These government agencies conduct systematic observations through climate, hydrology, and meteorology stations. Local research institutions and agencies also contribute significantly to the development of vulnerability assessments through collaboration, particularly in regional climate modelling efforts.

The impact and vulnerability assessment is conducted in Malaysia for a number of sectors, including water, coastal, agriculture, and the associated sub-sectors. The Malaysia National Communications 3 (NC3) included the sectoral assessments for dry spells in the Malaysian Peninsular and the Sabah and Sarawak regions (Ministry of Energy, Science, Technology, Environment, and Climate Change Malaysia, 2018). The assessment covers the impact of dry spells on reservoir storage and dam security, rice and irrigation water supply, loss of food production in some types of crops (e.g., rubber and cocoa), forest cover and biodiversity, and infrastructure.

Furthermore, the sector assessment highlighted water sector vulnerabilities. Some dry spell events are expected to occur at several river basins and coastal regions of Peninsular Malaysia, while more frequent events are expected for Sabah and Sarawak. Projections show that some dams have an increased probability of dry spells with 10-year or more return periods in 2040. This would result in lowered water levels and declining raw water quality due to less dilution.

In the agriculture sector, dry spells are expected to affect more than 350,000 hectares of rice cultivation areas. In 2030, it is estimated that more than 32% of the land will face dry spells with a return period of 10-20 years. Modelling for rubber crops in Peninsular Malaysia indicated that temperature rise and rainfall reduction could decrease production yield by up to 20% in 2050.

Overall, the existing research highlights significant vulnerabilities and impacts from dry spells across many different sectors. Further improvement to these assessments is imminent as it becomes increasingly important to ensure effective adaptation and mitigation measures in the face of climate change and disaster risks.

Mitigation measures in Malaysia mainly involve water rationing, in which the state controls the water allocation based on the water demand of relevant sectors. Additionally, cloud-seeding operations have been employed in Johor as an immediate drought response, particularly during critical water shortages. In severe drought episodes, the Johor government has even requested additional treated water from Singapore to meet demand (Chuah et al., 2018).

Additionally, long-term strategies are developed which focus on enhancing water supply and management. This includes plans for the development of non-conventional water resources, such as desalination plants and water reclamation facilities. There is also a growing recognition of the need for stronger water conservation policies to manage demand, as Johor's water consumption rates remain high. These efforts are vital to reducing the state's vulnerability to drought and ensuring the sustainable management of its water resources.

Malaysia's commitment to climate-resilient development is evidenced by the establishment of the National Steering Committee on Climate Change.

This committee operates under Malaysia's Ministry of Natural Resources and the Environment and coordinates Malaysia's strategies and policies regarding climate change adaptation and mitigation.

In addition, several NGOs and CSOs have implemented various programmes to mitigate the impact of drought on vulnerable communities. For example, the Global Environment Centre (GEC) and the Malaysian Water Partnership have worked on projects to improve water management during drought periods (GWP, 2020). These projects include raising awareness about water conservation, restoring wetlands, and enhancing local communities' resilience through the Sustainable Management of Peatland Forests initiative, which also serves as a natural buffer against drought.

Additionally, NGOs like MERCY Malaysia focus on disaster risk reduction, including providing emergency water supplies during droughts, delivering hygiene kits, and conducting training for local communities to better prepare for and respond to water scarcity (MERCY Malaysia, 2019). These organisations also support localised drought mitigation strategies such as rainwater harvesting and sustainable agricultural practices, aiming to ensure long-term community resilience to drought.

Despite the aforementioned efforts, there are limitations in the scope and reach of the existing programmes. For instance, funding is often limited, which restricts the government agencies, CSOs, or NGOs' ability to expand their operations beyond localised areas. Moreover, coordination between NGOs, CSOs, and government agencies remains fragmented, reducing the overall efficiency of drought management initiatives. Hence, strengthening partnerships between these groups and securing consistent financial support are essential to scaling these interventions and addressing drought vulnerabilities more comprehensively.

Gaps in Malaysia's drought management include the lack of real-time drought monitoring systems and the absence of a centralised database that can effectively guide water usage policies. For example, the Department of Irrigation and Drainage (DID) has struggled with integrating localised drought data across different regions, making it difficult to track drought progression and respond quickly (Prabhakar & Shivakoti, 2017). Additionally, while Pusat Ramalan dan Amaran Banjir Negara (PRABN) monitors flood events, there is no equivalent system fully developed for droughts. As a result, responses to emerging drought threats are often delayed or inadequately informed by real-time data.

Further challenges include weak inter-agency coordination. For instance, while the DID oversees water resources, state water authorities control water distribution, creating bureaucratic delays when timely interventions are needed. In Kedah, a region known for rice production, delays in water allocation decisions during the 2016-2017 drought had worsened crop losses because of poor coordination between state and national agencies. Another limitation is the lack of integration between water management policies and land-use planning. In many regions, agricultural expansion and deforestation continue without a clear alignment to water resource strategies, reducing the effectiveness of drought mitigation efforts. For example, in the state of Johor, rapid industrial and agricultural growth has caused over-extraction from local rivers, which in turn exacerbates water shortages during drought periods.

Concrete steps to address these gaps include the Malaysian Water Partnership's ongoing efforts to develop a national water management framework. Additionally, NGOs like the Global Environment Centre have advocated for better integration of land use and water policies, particularly through projects that restore wetlands to act as natural buffers against drought. Therefore, establishing a centralised real-time drought monitoring system, improving inter-agency coordination, and aligning land-use planning with water management policies are critical to enhancing Malaysia's drought resilience.

4.4. Myanmar

Current drought management in Myanmar involves the government’s active role in climate monitoring and forecasting. Climate monitoring and forecasting in Myanmar falls under the responsibility of the Department of Meteorology and Hydrology (DMH). DMH plays a crucial role in monitoring and forecasting weather patterns and issuing bulletins and reports on weather conditions, water levels, and drought severity. The department also provides near real-time updates on general weather conditions and issues rainfall warnings, though the latter are not consistently updated. Nevertheless, hydrological disaster monitoring primarily focuses on flooding, with limited attention given to drought events. This imbalance in disaster monitoring is notable, as no official documentation of a drought early warning system has been identified.

However, efforts are underway to enhance water stress and soil moisture monitoring capabilities through the utilisation of satellite data. These developments represent a step towards a more comprehensive climate monitoring, but significant gaps remain, particularly in drought management. The absence of a robust drought monitoring and early warning system could leave Myanmar vulnerable to the impacts of prolonged dry spells, which may increase in frequency and severity due to climate change.

Myanmar's vulnerability to meteorological drought is multifaceted, with significant implications for its agriculture-dependent economy and water resources. The agricultural sector, which contributes approximately 32% to the country's GDP and employs about 56% of the workforce, is particularly susceptible (Raitzer et al., 2015).

Other than monitoring and forecasting, the Myanmar Government has undertaken a climate change vulnerability assessment, provided by the (Ministry of Environmental Conservation and Forestry, 2012). Climate change vulnerability assessment is a comprehensive endeavour aimed at quantifying the impacts of climate change across various sectors. The assessment employs a vulnerability index calculation that takes into account three key factors: 'Vulnerability Level', 'Confidence Level', and 'Affected Level'. By combining these factors with population density, the assessment provides a nuanced understanding of vulnerabilities across different regions and sectors.

Furthermore, the vulnerability assessment identifies six key climate change impact parameters, including drought, which poses a significant threat to Myanmar's water resources, agriculture, and public health. The assessment reveals that the Dry Zone regions, particularly Mandalay and Bago, are particularly vulnerable to drought due to their reliance on irrigation and limited water resources.

The vulnerability assessment also mentions that drought vulnerability is classified as 'High' for regions in the dry zone, 'Medium' for the Bago Region and eastern mountain ranges, and 'Low' for the remaining regions except Yangon and Tanintharyi. In terms of sectoral vulnerability, the assessment indicates that public health is the most vulnerable sector, followed by biodiversity, water resources, forestry, coastal zones, and agriculture. This multi-sectoral vulnerability underscores the need for integrated adaptation approaches.

Overall, Myanmar's response to drought has involved a comprehensive strategy encompassing infrastructure development, technological adoption, and sustainable land management. Key initiatives include the construction of various water storage facilities, from small ponds to large reservoirs, to enhance water availability during dry periods. The government has also promoted the use of water-efficient irrigation technologies, such as drip and sprinkler systems, particularly in agricultural sectors.

The policy framework emphasises scientific inputs for land-soil-water management to ensure effective water resource management. Existing reservoirs under the Irrigation Department are being upgraded to optimise water use and expand irrigated lands. Furthermore, the government encourages local-level irrigation initiatives through small bunds and field ponds, fostering a multi-scale approach to water security.

The Irrigation Department has also undertaken significant efforts to improve water resource management through the construction and maintenance of dams, reservoirs, and water supply facilities. Moreover, the Ministry of Environmental Conservation and Forestry has implemented afforestation and land rehabilitation projects in drought-prone regions to enhance ecosystem resilience and reduce soil erosion.

The National Disaster Management Law in 2013 and the supporting Disaster Management Rules in 2015 established the foundational legal framework for drought management in Myanmar. This legislation created the basic structure for disaster response and management, including droughts, by defining institutional arrangements and responsibilities. The law also established a hierarchical disaster management system from the national to the local level, ensuring a coordinated approach to disaster risk reduction and response.

Building on the previously mentioned legal framework, the National Water Policy of Myanmar has addressed the specific challenges of water resource management. This policy has recognised drought as a significant water security issue and introduced key concepts such as Integrated Water Resource Management (IWRM) to form sustainable solutions. The National Water Policy of Myanmar also outlines strategies for drought mitigation through water storage infrastructure development, efficient irrigation systems, and the establishment of regulatory authorities for water management. The policy complemented the disaster management framework by focusing on the preventive and long-term aspects of drought management.

The Myanmar Action Plan for Disaster Risk Reduction (2017) further strengthens the operational aspects of drought management. The plan contains concrete strategies such as crop diversification and the promotion of drought-resistant varieties. Significantly, it calls for the development of an agricultural drought monitoring system through collaboration between the Department of Agriculture and the Department of Meteorology and Hydrology (DMH). The plan also establishes protocols for drought early warning, mitigation, response, and rehabilitation, complemented by capacity-building initiatives at the subnational level (National Disaster Management Committee, Republic of the Union of Myanmar, 2017).

In addition, a significant advancement came with the Myanmar Sustainable Development Plan (2018-2030), which integrates drought management into the broader context of sustainable development. This plan emphasises the interconnection between water security, ecosystem health, and climate resilience. The Ministry of Agriculture, Livestock, and Innovation (MoALI) and the Ministry of Natural Resources and Environmental Conservation (MoNREC) were also tasked with enhancing irrigation and drainage services and implementing more efficient water management systems. Additionally, these ministries, along with the Ministry of Labour, Immigration, and Population (MoLIP), were given the responsibility to promote the cultivation of drought-resistant crops, creating a multi-ministerial approach to drought resilience (Ministry of Planning and Finance, the Republic of the Union of Myanmar, 2018).

Concurrent with the Sustainable Development Plan, the Myanmar Climate Change Strategy and Master Plan (2018-2030) provides a comprehensive framework for addressing climate-related challenges, including drought. This strategy identifies specific adaptation measures for sectors affected by drought, particularly agriculture and water resources. It also emphasises the need for climate-smart agriculture practices and enhanced water management systems, complementing the objectives of the National Water Policy and the Sustainable Development Plan (Ministry of Natural Resources and Environmental Conservation, the Republic of the Union of Myanmar, 2018). Furthermore, the Myanmar Climate Change Policy (2019) emerged to build on the climate change strategic framework. This policy reinforces the country's commitment to addressing climate-related disasters, including droughts, which specifically calls for the adoption and implementation of efficient water management practices and technologies for water conservation (The Republic of the Union of Myanmar, 2019).

In response to increasing climate vulnerabilities in Myanmar's Dry Zone, multiple initiatives have been implemented to address water scarcity and drought conditions. From 2015 to 2019, a significant climate change adaptation project was carried out through collaboration between UNDP, the Adaptation Fund, and Myanmar's Ministry of Natural Resources and Environmental Conservation (MoNREC). Concurrently, international NGOs like Solidarités International have been working to provide immediate and long-term solutions to water access challenges, particularly crucial given the compounded effects of the political crisis and the COVID-19 pandemic.

A key outcome of these initiatives has been enhancing water availability in the region. Local organisations, supported by the UNDP project, has played a crucial role in implementing water capture and storage improvements and rehabilitating micro-watersheds. Complementing these efforts, Solidarités International has focused on rehabilitating water points and drilling new boreholes to ensure consistent water access. The NGO has also implemented an innovative approach of providing water through water trucking services to communities facing severe shortages, demonstrating the importance of combining both immediate relief and long-term solutions in addressing water scarcity.

The introduction of climate-resilient agricultural practices formed another vital component of the adaptation strategy. Local NGOs and farmer groups promoted drought-resistant farming techniques and improved post-harvest processing and storage methods. Solidarités International has enhanced these efforts by supporting communities with sustainable farming practices and providing emergency assistance to vulnerable households, ensuring food security despite challenging conditions. This multi-faceted approach addresses both immediate needs and long-term resilience building.

Community-based organisations have also developed climate-risk information systems, focusing on localised mapping and early warning communication networks. International NGOs' expertise in water resource management and community mobilisation have strengthened these grassroots efforts. Solidarités International's approach of working closely with local water management committees has enhanced community ownership and ensured the sustainability of water infrastructure, complementing the broader climate adaptation goals.

Both initiatives emphasise the critical role of local empowerment and community engagement. The UNDP project, which was implemented across five vulnerable townships, demonstrated the effectiveness of local organisations in addressing climate challenges. Similarly, Solidarités International's work has shown the importance of engaging local communities in water management, with a particular focus on training community members in infrastructure maintenance and water quality testing. This combined approach of international expertise and local knowledge has created a more resilient response to water scarcity.

While comprehensive in its policy coverage, Myanmar's drought management framework faces significant implementation challenges that hinder effective drought resilience. A primary concern is the limited technical capacity of climate-resilient technologies. Despite policies promoting advanced irrigation systems and water conservation techniques, there is a substantial gap between policy ambition and on-the-ground expertise. This technical deficit is particularly evident in deploying drought monitoring systems and implementing climate-smart agricultural practices, where the lack of skilled personnel and technical know-how impedes the adoption of innovative solutions.

Resource allocation remains a critical challenge. Despite ambitious policies for infrastructure upgrades and water management systems, financial resources often fall short. The spatial variation in drought risk across Myanmar further complicates this, requiring region-specific interventions and making resource prioritisation difficult. Data management and information sharing pose significant hurdles. Despite policy emphasis on monitoring and early warning systems, Myanmar struggles with inadequate data collection infrastructure and analysis capacity. This particularly affects transboundary water management and hampers effective vulnerability assessments needed for informed policy decisions. The complex interactions between vulnerable sectors complicate drought management efforts. While policies acknowledge interconnections between agricultural needs, water resource management, and development challenges, they often lack concrete mechanisms for cross-sectoral coordination. This leads to fragmented implementation of adaptation strategies, reducing their effectiveness.

4.5. Lao PDR

Lao PDR, like many Southeast Asian countries, faces increasing drought risks due to climate change and its heavy reliance on rain-fed agriculture. Droughts significantly impact water availability, food security, livelihoods, and the overall economy, especially in rural areas where most of the population depends on agriculture. The country's geographic and socioeconomic characteristics exacerbate its vulnerability to drought, and while progress has been made in addressing drought risks, considerable gaps remain in terms of monitoring, early warning systems, and community-level preparedness.

For drought monitoring, Lao PDR relies on general meteorological and hydrological data provided by the Department of Meteorology and Hydrology (DMH), along with tools like the Standardised Precipitation Evapotranspiration Index (SPEI) to track precipitation deficits, but the need for improvements in real-time data collection and early warning systems is critical for timely interventions. Lao PDR has made significant progress in developing drought early warning systems (DEWS) as part of its broader disaster risk management strategy. With support from the World Meteorological Organisation (WMO) and the Climate Risk and Early Warning Systems (CREWS) initiative, the country is enhancing its capacity to predict and manage droughts (WMO, 2024). Other efforts include the installation of hydrometeorological sensors by the Food and Agriculture Organisation (FAO) through the Strengthening Agro-climatic Monitoring and Information System (SAMIS) project. Additionally, the SAMIS project funded the Lao Climate Services for Agriculture (LaCSA), which utilises data from these sensors across Lao PDR to provide drought alerts and other critical agricultural information for farmers, suppliers, and planners. LaCSA centralises weather data from all stations in Lao PDR and generates agro-meteorological forecasts, which support decision-making for climate-smart agriculture.

Remote sensing and satellite data, provided through regional collaborations such as the MRC, help track drought risks. However, the systems are not highly localised or timely, particularly in rural areas. The MRC’s Drought Monitoring Tool plays a critical role in early warnings for the region, and local community-based systems, often supported by NGOs, provide basic warnings in remote areas. While programmes like LaCSA have contributed to improvements, Lao PDR's monitoring and early warning capacity remains limited. The DMH aims to collaborate with international organisations and donors to expand the network of hydrological and meteorological stations. Efforts are also underway to strengthen monitoring and forecasting capabilities, particularly through the development of a multi-hazard early warning system (MHEWS).

To enable a more proactive and holistic approach to disaster management, Lao PDR has adopted a multi-tiered governance system through the establishment of Disaster Prevention and Control Committees at the national, provincial, district, and village levels. Disaster damage and loss assessments, as well as data collection, are conducted from the bottom up. In contrast, early warning information is disseminated from the top down, allowing for timely communication and coordinated response across all administrative levels. Major gaps exists in terms of baseline data for hazard, exposure, vulnerability, risk, loss & damage data. These gaps pose a major challenge to conducting effective drought vulnerability and impact assessments in the country. Existing vulnerability assessments, such as those conducted by the United Nations Development Programme (UNDP), have identified that rural farming communities are particularly at risk, especially in provinces like Savannakhet and Champasak (UNDP, 2009). The assessments highlight the need for improved water management systems, drought-resistant crops, and more comprehensive drought early warning mechanisms to safeguard livelihoods.

Mitigation efforts in Lao PDR focus on improving water resource management and promoting agricultural adaptation strategies. These include enhancing irrigation efficiency and promoting the use of drought-tolerant crop varieties to sustain agricultural yields during drought periods. The management of hydropower infrastructure is also critical, as it can both mitigate and aggravate drought conditions depending on water flow regulation. Additionally, emergency measures such as the distribution of food and water aid during severe droughts are implemented, though logistical challenges, particularly in remote areas, limit the effectiveness of such responses. Utilisation of LaCSA for real-time weather and seasonal drought forecasts enables farmers to adjust planting schedules accordingly. Initiatives promoting circular economy practices, like local nutrient recycling, are also being explored to reduce reliance on vulnerable supply chains.

Lao PDR's drought mitigation and response efforts focus on both immediate relief and long-term resilience. The government, in partnership with international organisations such as the Asian Disaster Preparedness Center (ADPC), has implemented several drought mitigation programmes (ADPC, 2024). These include the construction of water reservoirs, irrigation systems, and community-based water management projects. ADPC also supports capacity-building initiatives that teach farmers drought-resistant farming techniques and water conservation practices. In response to severe droughts, the government activates emergency programmes that provide food and water supplies to affected communities. These programmes are often supported by international NGOs like DanChurchAid and Oxfam, which work closely with local governments to distribute aid and provide technical support.

Lao PDR has developed several policies aimed at reducing the impacts of droughts, including the National Disaster Risk Management Plan and the National Drought Management Strategy (WMO, 2024). These policies emphasise the importance of integrated water resource management, climate adaptation, sustainable agricultural practices, reforestation, sustainable land-use management, and the promotion of ecosystem resilience to drought through nature-based solutions. These policies are reflected in key frameworks such as the National Adaptation Program of Action (NAPA) and the National Climate Change Strategy. The government also collaborates with regional bodies such as the Mekong River Commission (MRC) to implement transboundary water management strategies that mitigate drought impacts across the Mekong Basin. Integration of LaCSA drought forecasts into national water planning optimises irrigation and water use efficiency. Farmer capacity-building programmes using LaCSA's climate advisories improve decision-making. While enhancement of SAMIS services strengthens early warning capabilities and reduces agricultural vulnerability to drought. The National Disaster Management Office (NDMO) coordinates disaster response efforts and works closely with international partners to ensure that policies are aligned with global best practices. Furthermore, the government has initiated awareness-raising campaigns to educate communities about drought risks and promote sustainable land use practices.

NGOs and CSOs play a crucial role in supporting community-level drought management and resilience-building, with a focus on food security, water management, and social protection:

- Food Security: NGOs provide training in sustainable agriculture and distribute drought-resistant seeds to help farmers cope with changing weather patterns.
- Water Management: Community-based water management initiatives are implemented to improve the efficient use of water resources during drought periods.
- Social Protection: NGOs contribute to drought relief and recovery efforts, offering critical support to vulnerable communities and improving local capacity to respond to drought-related crises.

UNDP and FAO support projects aimed at improving community resilience to drought by promoting sustainable agricultural practices, improving access to climate data, and building local capacity to manage water resources. For example, in the SAMIS project, FAO collaborated with the Ministry of Natural Resources and Environment (MONRE) and the Ministry of Agriculture and Forestry (MAF) to implement the LaCSA system. LaCSA collected weather data from all weather stations in Lao PDR, along with other agronomic data, to develop weather and climate models. These models provide valuable information such as advice for crop selection and yield forecast to help farmers plan and manage their crops effectively (Food and Agriculture Organisation (FAO), 2020). Such initiatives aim to empower local communities to adapt and enhance their agricultural resilience against climate-related risks.

FAO also serves as co-chair of the national technical working group on Anticipatory Action in Lao PDR, helping to convene multiple agencies and strengthen cross-sectoral coordination and collaboration in drought risk management. Anticipatory action aims to reduce and minimise the negative impacts of agricultural droughts on food security by preventing or lessening crop and livestock damage, thereby protecting farmers' income and livelihoods. The Anticipatory Action Protocol for agricultural drought in the Lao People's Democratic Republic (Lao PDR) was developed through close collaboration between the Ministry of Labour and Social Welfare, the Ministry of Agriculture and Forestry, and the Department of Meteorology and Hydrology under the Ministry of Natural Resources and Environment. This protocol is designed to be a living document, regularly updated based on experiences and lessons learned during testing with government partners (FAO, 2023).

To operationalise anticipatory action, the protocol in Lao PDR outlines a phased approach targeting high-risk areas such as Luang Prabang and Savannakhet. This includes a series of actions beginning with early warning messages, followed by the distribution of drought-resistant rice and bean seeds, training in agricultural techniques, and irrigation enhancement for farmers. In the final phase, multi-purpose cash transfers are deployed to support the most vulnerable. These efforts specifically target communities highly exposed to drought impacts, particularly households reliant on agriculture, those identified through social registries as living in poverty, and individuals with additional vulnerabilities such as disability, elderly status, or being single-parent households. This comprehensive approach ensures that anticipatory action is not only timely but also inclusive and grounded in the local context (FAO, 2023).

Additionally, organisations like Oxfam and DanChurchAid work on the ground to provide immediate relief during droughts and to support long-term adaptation strategies. These NGOs collaborate with the government to implement community-based programmes that focus on water management, crop diversification, and the development of drought-resilient infrastructure.

Government and NGO interventions in Lao PDR have resulted in improvements such as enhanced irrigation systems, increased awareness of drought risks, and the adoption of more resilient agricultural practices. The integration of LaCSA and SAMIS into national drought monitoring and mitigation strategies enhances resilience by providing timely, location-specific climate services to farmers and policymakers. However, several limitations persist. These include a lack of advanced technological infrastructure for accurate and timely data collection, delays in policy implementation, and a heavy reliance on external aid. Coordination between national and local stakeholders is often fragmented, and rural communities remain largely underserved in terms of access to drought information and resources. These challenges continue to hinder the development of long-term, independent drought resilience.

To strengthen its drought management efforts, Lao PDR requires external support in several key areas:

- Investment in real-time drought monitoring systems, particularly in rural areas, is needed to ensure timely and accurate early warnings.
- Local governments and communities need enhanced capacity to implement drought mitigation measures effectively.
- Advanced agricultural and irrigation technologies, as well as improved drought-resilient farming practices, are essential to bolster the country's resilience.
- Strengthening governance mechanisms to ensure that national policies are effectively implemented at the local level.
- Greater financial support from both domestic and international sources is required to invest in necessary drought resilience infrastructure and programmes.

4.6. Philippines

The Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) uses the SPEI to monitor drought, considering precipitation and evapotranspiration. This index, a variation of the SPI, is particularly useful for detecting agricultural droughts. PAGASA monitors short-term meteorological droughts with the 1-month SPEI and agricultural droughts with the 3-month SPEI, following the SPI User Guide. PAGASA provides gridded spatial maps of these indices, which help track drought conditions across provinces and regions. This data supports local and national drought assessment decision-making (PAGASA, n.d.).

In addition, PAGASA issues an El Niño Watch when there is a 55% or higher probability of El Niño within six months. These early warnings are critical for water and agricultural management (PAGASA, 2023). For instance, each irrigation system manager receives early warnings from PAGASA, which are then disseminated through the National Irrigation

Administration (NIA). The NIA, in turn, ensures that these warnings are distributed down to regional and local offices, enabling irrigation systems to take preventive measures in anticipation of water shortages caused by El Niño events. This coordinated communication system allows for timely responses to drought risks, protecting agricultural production and water resources across the country (Dawe et al., 2009).

Drought risk assessment, including the vulnerability assessment, in the Philippines is implemented at the local government level using the Climate and Disaster Risk Assessment (CDRA) Framework. The Philippines has a platform named GeoRiskPH, which provides access to risk-related data through an API. Through the Climate Change Commission (CCC), the Philippines has developed a module for Vulnerability and Risk Assessment (VRA) to estimate the vulnerability of various systems to the impacts of climate change, including drought. The vulnerability assessment uses several key indicators:

- **Exposure (E):** The presence (location) of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in areas exposed to drought hazards.
- **Sensitivity (S):** The susceptibility of a system (or community) based on its characteristics (or baseline data such as income, gender, livelihood, settlement location, population density, etc.) to drought hazards.
- **Adaptive Capacity (AC):** The ability to cope with and recover from the impacts of climate disasters.

The data for these assessments can be sourced from LGUs, PAGASA, MGO, PHIVOLCS, and other relevant sectoral agencies.

Drought impacts in the Philippines are evident in reduced crop yields, particularly rice and corn, which are staple crops. The country's low irrigation capacity exacerbates this issue; only about 13% of the total agricultural area is equipped for irrigation, with significant regional disparities. The country's vulnerability to drought is intensified by the irregular distribution of water resources, especially in drought-prone areas such as Mindanao and the Visayas (CIAT & DA-AMIA, 2017).

In response to water shortages, most irrigation systems implemented water rotation. Different parts of the irrigation system received water for three or four days, after which gates were closed, and water was shifted to other parts of the system. These rotation schemes are developed in consultation with representatives of farmer irrigation associations. Rotation is carefully planned to ensure fair treatment of the land and to maximise the cultivated area (Dawe et al., 2009).

The Philippines government has implemented several initiatives to mitigate drought risks, particularly through the Department of Agriculture (DA). The DA's El Niño Task Force is responsible for coordinating drought response efforts, including efficient water management, promoting the use of drought-resistant crop varieties, and cloud seeding operations to induce rainfall. The DA has also established the Adaptation and Mitigation Initiative in Agriculture (AMIA), which aims to build climate resilience in agriculture through drought-tolerant crop varieties and optimised irrigation systems (DA, n.d.). Additionally, the National Irrigation Administration (NIA) focuses on rehabilitating and expanding irrigation systems to address the lack of water resources during dry spells.

The Philippines government has a comprehensive approach to managing drought through disaster risk reduction policies. Key legislation includes the Climate Change Act of 2009 and the Disaster Risk Reduction and Management (DRRM) Act, which emphasise climate adaptation and disaster preparedness. The DA's National Color-Coded Agricultural Guide (NCCAG) Map is another key tool that helps farmers determine which crops are most suitable for different climate conditions, including drought .

Several NGOs and CSOs are actively involved in drought management in the Philippines. The AMIA has partnered with various NGOs to support community-based climate resilience efforts (CIAT & DA-AMIA, 2017). These organisations provide training on drought risk management, distribute drought-resistant seeds, and promote sustainable farming practices. International NGOs like Oxfam and CARE also work closely with local communities to implement water-saving technologies and build capacity for better drought preparedness.

In the Philippines, several gaps and limitations persist in the management of drought, which poses significant challenges to both rural and urban communities reliant on agriculture and water resources. One of the primary gaps is the inconsistency in the country's early warning systems for droughts. While the PAGASA provides weather forecasts and drought advisories, the integration of localised data, especially in remote areas, remains insufficient. Many areas affected by drought, such as in Visayas and Mindanao (PAGASA, 2024), face barriers to accessing timely and accurate data due to infrastructure limitations.

Another significant issue lies in the fragmented institutional coordination between national and local government agencies. Although drought management policies are in place, such as through the DA's climate resilience programmes, their implementation at the local level is often inconsistent. For instance, government efforts to promote climate-smart agricultural practices have been slow to reach many of the most drought-affected regions (Briones, 2017).

4.7. Thailand

Thailand's national drought management framework is embedded within a larger climate adaptation strategy that is part of the Climate Change Master Plan (2012-2050). This master plan focuses on preparedness, adaptation, and mitigation across several sectors, including agriculture and water management, sectors highly vulnerable to drought (The Office of Natural Resources and Environmental Policy and Planning, 2015). Specifically, the Bangkok Climate Change Master Plan (2013-2023) highlights the importance of sustainable water management, particularly in urban settings, while also addressing the need for improvements in waste-water treatment systems (Bangkok Metropolitan Administration, 2013). The integration of disaster risk management into urban and community planning is central to minimising the impacts of droughts and other climate-induced hazards.

In the agricultural sector, farmers in regions prone to water scarcity, especially in the Plaichumpol and Lam Pao irrigation projects, have been significantly impacted by recent severe droughts, leading to crop damage and poor-quality produce. Local responses have included shifting to drought-tolerant crops, reducing cultivation areas, and utilising supplementary water resources such as shallow wells and ponds. The Thai government has supported adaptation by promoting the use of these water-saving technologies and improving infrastructure for irrigation in affected areas. The National Waste Management Master Plan (2016-2021) also aligns with this objective by addressing the issue of water scarcity and waste treatment, thus preventing water pollution that could exacerbate drought conditions (Ministry of Natural Resources and Environment, the Kingdom of Thailand, 2016).

Thailand has established a comprehensive monitoring and early warning system as part of its disaster management strategy, led by the Department of Disaster Prevention and Mitigation. This system includes risk mapping for flood and drought scenarios, which helps predict and assess vulnerabilities associated with climate change. As of 2016, these maps were utilised for disaster risk assessment, exposure vulnerability evaluations, and capacity-building initiatives at the national and regional levels. Furthermore, Phase 2 of the National Adaptation Plan (NAP) developed by the Office of Natural Resources and Environmental Policy and Planning (ONEP) integrated a database of best practices, enhancing local adaptation measures through practical examples.

Early warning systems have proven critical in notifying communities in both irrigated and rain-fed areas about impending droughts, allowing them to implement preemptive measures, such as reducing water consumption or shifting crops. However, the effectiveness of these systems depends largely on local infrastructure and capacity, which vary significantly across Thailand’s regions. Further investments are required to enhance the reach and efficiency of early warnings, particularly in rural areas that are more dependent on rain-fed agriculture.

The Climate Change Master Plan (2012-2050) identifies key vulnerabilities for sectors such as small-scale agriculture and traditional fisheries, emphasising their exposure to climate-induced risks, including drought (The Office of Natural Resources and Environmental Policy and Planning, 2015). Studies in areas like the Plaichumpol Irrigation Project (central Thailand) and the Lam Pao Irrigation Project (northeast Thailand) show that severe droughts between 2015 and 2016 had widespread effects on rice farmers, particularly in rain-fed areas. Impacts included reduced yields, pest infestations due to extreme dry conditions, and loss of income.

In the central plains, farmers adapted by reducing their cultivation areas and growing less water-intensive crops. Those in rain-fed areas of the northeast adopted similar measures, with many turning to groundwater sources or even temporarily discontinuing farming. The vulnerability assessment of these regions informed the drafting of Thailand's National

Adaptation Plan (NAP), which targets localised adaptation efforts. The NAP's vulnerability and risk mapping integration ensures that these at-risk areas are prioritised in future adaptation initiatives.

At the farm level, drought adaptation strategies have included reducing crop areas, switching to drought-resistant crops, and increasing reliance on supplementary water sources such as groundwater. While effective at mitigating short-term impacts, these efforts highlight the broader challenge of long-term adaptation, as farmers often lack the financial resources and infrastructure to adjust fully. Government support has been critical in providing loans and technical assistance to farmers, though challenges persist in ensuring that all regions benefit equally from these resources.

On a national scale, Thailand's commitment to sufficiency economy principles in the Climate Change Master Plan encourages a sustainable approach to development, where drought resilience is built through minimising dependence on external resources. Additionally, the Energy Efficiency Plan (EEP2015) and the Alternative Energy Development Plan (AEDP2015) aim to reduce greenhouse gas emissions, thus contributing indirectly to mitigation by addressing the root causes of climate change, which exacerbate drought conditions.

The 20-Year National Strategy, initiated alongside the 12th National Economic and Social Development Plan, provides a comprehensive framework for Thailand’s long-term development goals, including climate resilience and drought management. Additionally, sector-specific policies, such as the Fourth National Strategic Plan on Chemical Management (2012-2021) and the Thailand Industrial Development Strategy 4.0, promote environmental sustainability and reduced resource consumption, essential for managing water scarcity.

While the provided information does not directly address non-governmental initiatives, it can be inferred that various local and international NGOs contribute to drought resilience through community-driven projects, awareness campaigns, and capacity-building efforts in rural areas. These programmes often complement governmental policies by filling in gaps in infrastructure and resources at the local level.

The adaptation measures implemented by Thailand have yielded mixed results. While farmers have managed to reduce losses by adjusting crop types and water usage, the financial burden of droughts remains high. Loans and other forms of financial support have been helpful but may not be sustainable in the long term if droughts increase in frequency or severity due to climate change. Moreover, the reliance on shallow groundwater and other supplementary water sources highlights the vulnerability of Thailand's agricultural sector to water scarcity, particularly in regions with limited access to advanced irrigation systems.

Three key areas of support are identified in Thailand's adaptation framework:

- Community and Urban Planning
  Investment is needed to avoid inundation and mitigate the impacts of drought in high-risk areas, particularly in the context of urban expansion and the growing demand for water resources.

- Infrastructure Investments
  Hard structures such as flood barriers and irrigation systems must be expanded to protect agricultural and coastal areas from the impacts of climate change, particularly rising sea levels and drought.

- Soft Structures
  Improved regulations, public services, and awareness campaigns are critical to enhancing adaptive capacity at the community level. The National Adaptation Plan (NAP), currently being piloted in regional areas, aims to bridge this gap by integrating local knowledge and best practices into national strategies.

4.8. Vietnam

Vietnam faces significant drought risks, which have been amplified by climate change and the increasing variability of weather patterns. Droughts in Vietnam manifest as both meteorological and hydrological droughts. Managing droughts is critical, as seen in the severe droughts experienced between 2015 and 2017, which had wide-reaching impacts on agriculture, water resources, and the livelihoods of millions of people.

Vietnam's drought monitoring and early warning systems integrate meteorological, hydrological, and agricultural data to predict and mitigate drought impacts. The country utilises a network of hydrometeorological stations, satellite data, and tools like the SPI and Vegetation Health Index (VHI) to monitor rainfall, soil moisture, and vegetation health. Key systems, like the National Early Warning System (NEWS), provide forecasts and real-time alerts to local communities and government agencies. Mobile platforms and community-based warning systems help disseminate timely information, while challenges remain in data integration, technical capacity, and funding. Vietnam is working to enhance its systems through satellite advancements and international collaboration.

Droughts in Vietnam pose severe threats to both rural and urban areas, particularly the agriculture sector, which is heavily dependent on rainfall. Regions like the Mekong Delta are particularly vulnerable, where agricultural productivity relies on consistent water availability. Water scarcity leads to crop failures, loss of livestock, and reduction in the capacity of water storage, severely affecting food security and rural incomes.

During the 2015–2017 drought, regions across Vietnam suffered significant impacts, particularly in the Mekong Delta and Central Highlands. Prolonged dry spells reduced river flows, caused groundwater depletion and exacerbated salinity intrusion. This drought directly affected over 2 million people, with losses in rice production and other agricultural activities leading to economic losses estimated at $USD 674 million.

Vietnam has taken various steps to mitigate the impacts of droughts and improve response mechanisms:

1. Water Resource Management: Efficient water management systems have been implemented, particularly in drought-prone regions like the Mekong Delta. These include the construction of reservoirs, improvements in irrigation infrastructure, and the development of water reuse and recycling systems. Moreover, managing groundwater resources more effectively, such as preventing over-extraction, has become a priority to ensure long-term water security.

2. Saline Intrusion Management: Vietnam has implemented measures to manage saline intrusion during droughts in coastal regions like the Mekong Delta. These include the construction of dams and embankments, which help prevent saltwater from contaminating freshwater sources used for agriculture. Additionally, agricultural adaptations have been promoted, such as introducing salt-tolerant crop varieties.
3. Crop Diversification: The agricultural sector has been encouraged to diversify crops, focusing on drought-resistant varieties. This includes using new hybrid rice varieties designed to withstand lower water availability and higher salt concentrations. Moreover, rotational farming and using different cropping patterns aim to optimise the use of limited water resources.
4. Technological Interventions: Vietnam is rapidly adopting technological solutions for water conservation and drought response. These include smart irrigation systems that use sensors to monitor soil moisture levels, reducing water wastage and optimising irrigation efficiency. Additionally, research and development are being conducted to create new agricultural practices that are more resilient to water shortages.

Vietnam's government has implemented a range of policies across various sectors to address drought and climate adaptation. In the environmental sector, Resolution No.24-NQ/TW of 2013 emphasises climate change response and natural resource management, targeting the reduction of drought risks. The Target Program for Climate Change and Green Growth (2016–2020) further incorporates drought management, focusing on enhancing water security, promoting water-saving technologies, and improving irrigation infrastructure. The National Water Resource Strategy also plays a key role in improving water management to address drought vulnerabilities.

1. For the agricultural and food security sector, the Mekong Delta Plan concentrates on sustainable water resource management, preventing saline intrusion, and improving irrigation systems to boost agricultural resilience. Similarly, the Action Plans by the Ministry of Agriculture and Rural Development (MARD) promote drought-resistant crops, water-efficient farming techniques, and infrastructure upgrades.

2. In the social sector, these programmes support rural communities by enhancing their capacity to adapt to water scarcity and drought impacts, fostering sustainable livelihoods.

Several NGOs and CSOs are actively engaged in drought management efforts:

1. World Bank: The World Bank has been involved in projects aimed at enhancing Vietnam's water management systems. The initiatives include funding for irrigation infrastructure and drought mitigation projects, particularly in vulnerable regions like the Central Highlands.
2. International NGOs: Organisations such as Oxfam and CARE International have implemented programmes focused on building the resilience of rural communities to drought. These programmes promote sustainable farming practices, water conservation techniques, and community-based drought management strategies.

While Vietnam has made significant progress in drought management, several challenges remain. The outcomes of interventions include improved water infrastructure, greater awareness of drought risks, and better agricultural practices that reduce vulnerability. However, the long-term sustainability of these interventions is uncertain, particularly given the increasing frequency and severity of droughts due to climate change. Some gaps and limitations include:

- Funding Gaps: Many projects, especially at the local level, are underfunded or lack the resources needed for full implementation. For example, MARD’s action plans require significant investment, yet only a portion of the needed funding has been secured.
- Coordination Issues: There is a need for better coordination among various government sectors and between national and local authorities. This includes integrating water resource management policies across agriculture, environment, and urban development sectors to ensure a holistic approach to drought management.
- There is a gap in cross-sectoral coordination in Vietnam’s drought management strategies, which limits the effectiveness of

interventions across different sectors (e.g., food, water, and environment). Stronger institutional frameworks are needed to integrate climate change adaptation, water management, and agricultural policies.

- While technology-based solutions are being adopted, there is a need for increased investment in modern irrigation systems, water conservation technologies, and agricultural innovations that could more effectively mitigate drought risks.
- Greater emphasis on community involvement in drought management is needed. Local farmers and rural communities require more support and training in sustainable water use practices and crop diversification.
- Vietnam needs more international collaboration and financial support to implement its drought mitigation and adaptation plans fully. Global institutions and donor agencies can play a critical role in closing the funding gaps and providing technical expertise for drought management.

5. Recommendations

5.1. Lessons Learned and Policy Recommendations to Strengthen the Three Pillars of Drought Management

The analysis of drought management practices across Southeast Asian countries has revealed valuable insights and opportunities for improvement across the three pillars of drought management: monitoring and early warning systems, vulnerability and impact assessment, and mitigation and response. This section presents an integrated overview of key lessons learned and corresponding policy recommendations to enhance drought resilience in the region.

A primary lesson from countries with more advanced systems, such as the Philippines and Thailand, is the critical importance of comprehensive and integrated monitoring networks. These countries have demonstrated that combining satellite data with ground-based observations significantly improves the accuracy and coverage of drought monitoring. Moreover, the implementation of community-based early warning systems has proven valuable in complementing national efforts, especially in remote areas where centralised monitoring may be less effective.

Vulnerability assessments have emerged as a cornerstone of effective drought management. Thailand's Climate Change Master Plan and the Philippines' Climate and Disaster Risk Assessment (CDRA) Framework exemplify how comprehensive, multi-sector assessments can provide a solid foundation for targeted interventions. These assessments are most effective when they integrate both biophysical and socio-economic factors, providing a nuanced understanding of drought vulnerabilities at various scales.

In terms of mitigation and response, countries like Vietnam have shown that diversification strategies can significantly enhance resilience to water scarcity, such as promoting drought-resistant crops and varying cropping patterns. Additionally, Thailand's investments in irrigation infrastructure highlight the crucial role of physical interventions in drought mitigation. These examples underscore the importance of combining policy-driven initiatives with community-based adaptation strategies to build comprehensive drought resilience.

Based on these lessons, several key policy recommendations are proposed to strengthen drought management at national level across Southeast Asia:

1. Prioritise the development of low-cost, robust, and sustainable real-time data collection infrastructure, particularly in rural and remote areas. This should include the integration of satellite data, ground-based observations, and community-based monitoring networks. Adopting standardised drought indices (e.g., SPI, SPEI) across the region would ensure consistent monitoring and facilitate regional cooperation.
2. Strengthen the link between monitoring data and actionable response plans. This can involve improving communication channels to ensure timely dissemination of drought warnings to all stakeholders, including remote and vulnerable communities.
3. Implement standardised vulnerability assessment methodologies that can be adapted to local contexts. These assessments should integrate socio-economic factors alongside biophysical data and be regularly updated to reflect changing conditions. Capacity building at local government levels is crucial to ensure the effective utilisation of these assessments in planning and decision-making processes.

4. Promote the adoption of drought-resistant crop varieties and water-efficient farming techniques, which can be supported by robust research and extension services to ensure widespread adoption and adaptation to local conditions.
5. Strategically invest in water storage and irrigation infrastructure, focusing on areas identified as highly vulnerable to drought guided by comprehensive water resource management plans that consider immediate needs and long-term sustainability.
6. Encourage the development of comprehensive drought management plans that include short-term response mechanisms and long-term resilience-building strategies.
7. Establish clear institutional frameworks for drought response, ensuring effective coordination between national and local levels, including cross-sectoral collaboration.
8. Enhance regional cooperation for data sharing, joint research initiatives, and the development of integrated early warning systems.
9. Ensure that drought management strategies are aligned with broader climate change adaptation efforts.
10. Create platforms for regular stakeholder engagement in drought planning and response at national and local levels.

5.2. Priority Countries for Assistance

Based on the analysis of current drought management practices across Southeast Asia, there are gaps faced by each country. Table 1 shows the main gaps and challenges in drought management practices faced by each country in Southeast Asia.

Table 1. Main Gaps in Drought Management Practices by Each Country in Southeast Asia

Country	Gaps
Cambodia	1. Insufficient technical capacity and resources 2. Inadequate monitoring infrastructure 3. Challenges of implementing policies at the local level 4. Ineffective drought early warning systems in rural areas
Indonesia	1. Equalisation in addressing regional-scale drought hazards due to the large area

	2. Lack of standardised frameworks and methodologies between multiple agencies
Lao PDR	1. Limited real-time drought monitoring capacity, especially in remote areas 2. Fragmented coordination between national and local stakeholders 3. Lack of advanced infrastructure 4. Delays in policy implementation 5. Heavy reliance on external aid 6. Rural communities remain largely underserved
Malaysia	1. Lack of real-time drought monitoring systems 2. Lack of centralised database that can effectively guide water usage policies
Myanmar	1. Limited technical capacity 2. Substantial gap between policy ambition and on-the-ground expertise 3. Inadequate data collection and early warning infrastructure 4. Insufficient financial resources 5. Lack concrete mechanisms for cross-sectoral coordination
The Philippines	1. Insufficient integration of localised data, especially in remote areas 2. Fragmented coordination between national and local stakeholders
Thailand	1. High reliance on agriculture and groundwater
Viet Nam	1. Funding gaps and lack of resources in projects 2. Several unclear cross-sector coordinations

Based on the summarised gaps in Table 1, three countries have been identified as priorities for support in upgrading their drought management capabilities: Cambodia, Lao PDR, and Myanmar. Addressing these issues requires targeted interventions in early warning systems, data collection, framework, and infrastructure development. The table below outlines the drought management key challenges, existing strategies/policies, and recommendations for each country:

Table 2. Drought Management Key Challenges, Existing Strategies / Policies, and Recommendations for Prioritised Countries in Southeast Asia

Country	**Key Challenges**	**Existing Strategies / Policies**	**Recommendations**
Cambodia	Insufficient technical capacity for drought risk and impact assessment, particularly for rural communities	Law on Disaster Management, Law on Water Management, The National Action Plan for Disaster Risk Reduction (DRR), The Cambodia Climate Change Strategic Plan (CCSP), Climate Action Plan for Water Resources and Meteorology	Strengthening early warning systems, drought monitoring, drought forecasting, drought impact assessment, and integrated drought management framework
Lao DPR	National strategies do not specifically cover drought	National Socio-Economic Development Plan (NSEDP), Disaster Management Law Law on Meteorology and Hydrology, Climate Change Decree, National Strategy on DRR, National Strategy on Climate Change Towards 2030	Develop government institutional and policy framework for drought management & EWS, Developing localised drought impact assessments and response strategies
Myanmar	Limited capacity for drought monitoring and	Myanmar Climate Change Strategy and Action Plan (MCCSAP), National	Strengthening drought mitigation infrastructure (e.g., irrigation, water storage)

	prediction	Adaptation Programme of Action (NAPA), National Water Policy	

A closer look at these challenges highlights critical gaps in early warning systems, data availability, and institutional capacity. Strengthening drought resilience in these countries requires addressing these issues in a structured manner:

1. Cambodia, with its highly vulnerable rural communities, lacks robust early warning systems and suffers from inadequate drought mitigation infrastructure. Uncoordinated data collection on drought losses and damages also increases the challenges in assessing the impact of drought in Cambodia. Building upon existing initiatives such as EWS 1294, Cambodia Disaster Damage & Loss Information System, and PRISM will help address those gaps. Strengthening irrigation and water storage systems while integrating IWRM into national water and agricultural policies would support a more sustainable and adaptive approach to drought management.
2. Lao PDR faces difficulties in real-time drought monitoring, particularly in remote areas where data collection remains a major challenge. National strategies do not specifically cover drought and fragmented coordination between national and local institutions also increases the challenges in managing drought risks in Lao PDR. Developing government institutional and policy framework for drought management & EWS, Prioritise the development of low-cost, robust, and sustainable real-time data collection infrastructure, especially for rural areas, encourage data sharing practices and use of regional datasets, and improving multi-level governance capacity for IWRM adoption would help enhance drought preparedness.
3. Myanmar struggles with weak early warning systems and limited drought monitoring capacity, which reduces its ability to predict and respond to drought events. Strengthening data collection infrastructure and enhancing cross-sectoral coordination through IWRM would improve its overall drought resilience.

Given the technical, financial, and institutional limitations of these countries, international support should prioritise technology transfer, capacity building, and financial assistance to facilitate comprehensive IWRM-based drought management strategies. Strengthening these areas would enhance the region's overall drought resilience, ensuring more sustainable water management and improved livelihoods for vulnerable communities.

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