

El Niño

A Review of Scientific Understanding and the Impacts of 1997/98 Event in Malaysia

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ACRONYMS

APCC	APEC Climate Center
APEC	Asia-Pacific Economic Cooperation
API	Air Pollution Index
AR5	Fifth Assessment Report (IPCC)
ARI	Average Recurrence Interval
ASEAN	Association of Southeast Asian Nations
ASM	Academy of Sciences Malaysia
CCA	Canonical Correlation Analysis
CFS	Canadian Forest Service
CPC	Climate Prediction Center (NOAA)
DDSOP	Drought Disaster Standard Operating Procedure
DID	Department of Irrigation and Drainage
DJF	December-January-February
DOE	Department of Environment
DOSM	Department of Statistics Malaysia
DRR	Disaster Risk Reduction
EEOF	extended empirical orthogonal function
EEPSEA	Economy and Environment Program for Southeast Asia
EMI	El Niño Modoki Index
ENSO	El Niño Southern Oscillation
FDRS	Fire Danger Rating System
FFB	fresh fruit bunches
FRIM	Forest Research Institute Malaysia
GCM	General Circulation Model
GDP	Gross Domestic Product
GTS	Global Telecommunication System
GWP	Global Warming Potential
HFA	Hyogo Framework for Action
IDM	Integrated Drought Management
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society [United States]
ISV	Intra-seasonal Variability
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
JJA	Jun-July-August
JMG	Department of Minerals and Geoscience Malaysia
KA	key action
KeTTHA	Ministry of Energy, Green Technology and Water
MAM	March-April-May
MARDI	Malaysian Agricultural Research and Development Institute
MP	Malaysia Plan
MJO	Madden-Julian Oscillation
MMD	Malaysian Meteorological Department
MOA	Ministry of Agriculture & Agro-Based Industry
MOE	Ministry of Education
MOH	Ministry of Health
MOS	Model Output Statistics
MOSTI	Ministry of Science, Technology and Innovation
MPOB	Malaysian Palm Oil Board
NAHRIM	National Hydraulic Research Institute of Malaysia
NAO	North Atlantic Oscillation
NCEP	National Centers for Environmental Prediction

NOAA	National Oceanic and Atmospheric Administration [United States]
NRE	Ministry of Natural Resources and Environment
NSC	National Security Council
PAH	Polycyclic Aromatic Hydrocarbon
PDO	Pacific Decadal Oscillation
PSI	Pollutants Standard Index
R&D	Research and Development
RH	Relative Humidity
RHAP	Regional Haze Action Plan
RM	Ringgit Malaysia (Malaysian Ringgit)
SDG	Sustainable Development Goal
SEA	Southeast Asia
SEANDRR	South-East Asia Network for Drought Risk Reduction
SOI	Southern Oscillation Index
SON	September-October-November
SPI	Standard Precipitation Index
SST	Sea Surface Temperature
STIPAC	Science, Technology and Innovation Policy Advisory Committee
TAO	Tropical Atmosphere OceanTmax Maximum Surface Air Temperature
TOGA	Tropical Ocean-Global Atmosphere
TSP	Total Suspended Particulates
UN	United Nation
UNCCD	United Nations Convention to Combat Desertification
UNCED	UN Conference on Environment and Development
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
CBD	Convention on Biological Diversity
UNICEF	United Nations Children's Fund
UNISDR	United Nations International Strategy for Disaster Reduction
US$	United States Dollar
WHO	World Health Organization
WTP	water treatment plant
WWB	Westerly Wind Burst
WWF	World Wide Fund for Nature (formerly World Wildlife Fund)

Chemical Formulae

Al	Aluminium
C2H6	Ethylene
CO2	Carbon Dioxide
KCl	Potassium Chloride
Na+	Sodium
NH4Cl	Ammonium Chloride
NO3-	Nitrate
SO2	Sulphur Dioxide
SO42-	Sulphate
Ti	Titanium
Zn	Zinc

Unit Measurements

Gt	Gigaton
Ha	Hectare
Kg	Kilogram
kWh	Kilowatt-hour
MJ	Megajoule
mld	Million Litres Per Day
mm	Millimetre
Mt	Million Tonnes
MW	Megawatt
cm	centimetre

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Chapter 3:
Environmental, social and economic impacts of the 1997/98 El Niño event in Malaysia
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Chapter 4:
Coping with drought: Lessons learned from the 1997-98 El Niño event
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Chapter 5:
Conclusions and Policy Recommendations
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Scientific Understanding

The El Niño – Southern Oscillation (ENSO) events are phenomena that resulted from coupled interactions between the atmosphere and ocean in the tropical Pacific Ocean. Its effects around the globe are tele-connected through disruption in the Walker Circulation and anomalous regional air-sea interaction. The typical coupling with warming at the eastern region of the Pacific Ocean is referred to as conventional ENSO with conventional El Niño (La Niña) as its warm (cold) phase. There is also a tendency for the coupled atmosphere-ocean system to evolve differently with the maximum warming located in the central region rather than the eastern part of the Pacific Ocean. This coupling is recognised as a different mode of the tropical Pacific Ocean coupled system and known as the El Niño – Southern Oscillation (ENSO) Modoki. The warm (cold) phase of this mode of coupling is El Niño (La Niña) Modoki.

The different positions of heating in the tropical Pacific Ocean induce different perturbations to the Walker Circulation and exert different impacts and climate anomalies around the world. In Malaysia and the greater Southeast Asian region, conventional ENSO and ENSO Modoki exert different impacts. During June-July-August of the conventional El Niño year (JJA(0)), Peninsular Malaysia, Sumatra and southern Borneo experience drought conditions, which are often associated with severe haze episodes. During September-October-November (SON(0)), southern parts of Sumatra, Java and the entire Borneo experience drier-than-normal condition. During this period, the condition over Peninsular returns to normal. However, haze episodes could still develop during this period due to the dry conditions over Sumatra and Borneo. During December through January and February of thefollowing year (DJF(0/1)), the drought condition persists over northern Borneo and southern Philippines but over other regions (Peninsular Malaysia, Sumatra, southern Borneo), the conditions return to normal. During the ending phase of a conventional El Niño, only the northern tip of Borneo, southern Philippines and Indochina regions are affected. In contrast to the conventional type, El Niño Modoki exerts drier condition to both northern Borneo (Sabah and Sarawak) and Peninsular Malaysia (especially northern region) during DJF(0/1).

On an interannual timescale, Malaysian climate is modulated by the ENSO with generally drier than normal condition during El Niño and wetter than normal condition during La Niña. However, the severity of these conditions depends on the season and the location as well as the strength of the event. A recent study shows that most drought episodes in Malaysia are associated with El Niño. The region that experiences rainfall deficit or drought condition does not only vary seasonally but also spatially. The ENSO events are largely predictable within certain levels of uncertainties by at least 6 months to a year lead-time. With real-time observations of the current states of the atmosphere and ocean in the tropical Pacific Ocean, and forecasts provided by the Climate Prediction Center, National Oceanic and Atmospheric Administration (NOAA), United States of America, ENSO development can basically be monitored and tracked.

In addition to ENSO, Malaysia is also influenced by Indian Ocean Dipole (IOD) and Madden-Julian Oscillation (MJO). The impacts of IOD on the Malaysian climate are less clear but a recent study seems to suggest that IOD could enhance the severity of a drought episode if it co-occurs with an El Niño episode. MJO is characterised by eastward propagation of alternating large-scale enhanced and suppressed convective systems

from the Indian Ocean to Pacific Ocean and these often cause drought and flood over the Maritime Continent region, including Malaysia. Extreme events can also occur because of interactions of these phenomena. Apart from natural variability, Malaysian climate also experiences long-term changes associated with global climate change. For example, it has experienced significant increase of mean temperature and extreme events since the middle of the 20th century.

Coupled with various forecasting systems, and within certain levels of uncertainties, the development of ENSO can be largely predicted and tracked in almost real time. Malaysia needs to monitor this phenomenon using forecast products from established forecast centres. In addition, Malaysia also needs to increase its research on local and regional climate variability and build its own seasonal forecasting system.

Environmental, Social and Economic Impacts and Costs

The prolonged drought induced by the 1997/98 El Niño event (May 1997 – April 1998) in Malaysia caused profound impacts on environmental, social and economic sectors, which are interlinked and each has knock-on effects on the others. The economic-wide impacts are unknown but expected to be enormous.

Constraint on the availability of water resources significantly affected the productivity of agriculture (e.g., oil palm yield/ha decreased by 16.8% and paddy yield/ha decreased by 11.3%). However, the rubber yield did not seem to have been affected by the El Niño event, at least not noticeable over a short-term. The prolonged drought also affected the fruit setting of Cocoa Production.

There was a significant decrease in hydropower (i.e., 23.8% from 1996 to 1997), made up by the increased use of diesel and gas-generated electricity, implying a higher emission of greenhouse gases. The Gross Domestic Product (GDP) contributed by manufacturing decreased by 4.7% from 1996 to 1998. The decrease in GDP in 1997 and 1998 was largely due to the regional financial crisis exacerbated by the impacts of the El Niño event that affected the agricultural and industrial productivity.

Enhanced sea surface temperature (SST) during the 1997/98 El Niño event affected the marine ecosystems, including fishery and coral bleaching, while enhanced air temperature affected terrestrial ecosystems, public health and air quality due to the production of photochemical smog under strong sunlight. The worsening air quality was compounded by the transboundary haze caused by biomass burning in Indonesia during the prolonged drought period. The transboundary haze reduced visibility, disrupted air flights, affected school activities and tourism. The health of high-risk groups such as children, senior citizens, smokers, people who work outdoors or sufferers of asthma, bronchitis, pneumonia, chronic lung diseases, cardio-vascular problems or allergies were also affected. Nipah Virus outbreak, a disease the Malaysian government was unprepared for, was linked to the prolonged drought.

Wild fires were reported at a few locations in East Malaysia during the 1998 drought period. In Sabah, about 1,580 km2 was engulfed in wild fire, of which more than 100 km2 were agricultural lands. The hill paddy crops in some villages were totally destroyed prompting authorities to send food supply. A similar situation was experienced in the north-eastern part of Sarawak near Miri. A number of districts exercised water rationing to ease off the drought situation.

The 1997/98 El Niño event brought widespread economic losses across South-East Asia, including Malaysia. It was reported that in Peninsular Malaysia and Sabah alone, more than 2,797 km2 and 170,000 people, including 7,200 farmers were directly affected. Tawang et al. (2002) estimated the total economic loss of oil palm, rubber and rice from 1980 to 1999 due to the effects and impacts of El Niño events and it was more than RM3.3 billion, excluding the various secondary spin–off losses resulting from other downstream activities. Of these losses, oil palm production accounted for RM2.651 billion[1](or about 80.3%), followed by rubber, RM357 million[2] (or about 10.8%) and rice, RM218 million[3] (or about 0.6%). These had resulted in the loss of foreign exchange because of the loss from potential export earnings of palm oil (estimated at RM2,129 million in 1998) and rubber (estimated at RM179 million), as well as the need to import more rice to meet the country's demand. However, significant productivity losses for other agricultural subsectors, such as fruits, vegetables, sugarcane, and selected livestock industries were not evident. For the 1997/98 El Niño event, the economic losses of oil palm and paddy were estimated at RM1,982.0 million and RM159.6 million respectively for the year 1998. No estimate of economic loss for rubber was provided for 1998.

The total direct and indirect costs due to the 1997/98 El Niño event for Malaysia are unknown, though various costs have been reported without given proper methodologies or peer-reviewed references. However, a more systematic study estimated that the total economic losses in Malaysia associated with the transboundary haze episode during August-October 1997 amounted to RM801.9 million (or US$321 million at 1997 exchange rate). These losses were partly due to the loss in productivity during the state of emergency in Sarawak from 19 to 28 September 1997, RM393.51 million (USS$157.4 million), which accounted for 49.07%; followed by decline in tourists arrival, which accounted for RM318.55 million (US$ 127.42 million), or 39.72%; and decline in fish landing, RM40.58 million (US$ 16.23million) or 5.00%; cost of fire-fighting, RM25 million (US$ 10million) or 3.12%; adjusted cost of illness RM21.02 million (US$8.41 million) or 2.62%; cloud seeding, RM2.08 million (US$0.83million) or 0.26%; expenditure on masks, RM0.71 million (US$0.28 million) or 0.09%; and cancellation of flights, RM0.45 million (US$0.18 million) or 0.06%, respectively. However, the above estimate was very conservative as it did not account for the economy-wide costs, and the losses in biodiversity and ecosystem services were also not estimated. It would be useful to assess the total cost over the whole period of the El Niño event. Malaysia's estimated total cost of damage due to fires and haze during August-October 1997 was about 3.3 times lower than that of Indonesia, but 4.2 times higher than that of Singapore. The total combined cost was estimated at about US$4.5 billion for Indonesia and other ASEAN countries. This estimate was also conservative. It is likely that the actual total cost could be at least a few orders of magnitude higher if the period for assessment was extended to the whole period of the haze episode until 1998.

[1] For the years 1982, 1983, 1991 and 1998. See Table 5.5 of Tawang et al. (2002).
[2] For the years 1981, 1982 and 1990. See Table 5.8 of Tawang et al. (2002).
[3] For the years 1980, 1981 and 1998. See Table 5.11 of Tawang et al. (2002).

Coping with El Niño: Lessons learned

Despite the escalating impacts of drought (recurrent drought, El Niño-induced or climate change-induced drought), very few developing countries, including Southeast Asian countries, are able to effectively respond to and cope with these events. There is a lack of emphasis on the development of national policies and response measures for drought risk reduction, including drought disaster management, based on the best available scientific data and information. In addition, the lack of human and institutional capacity to cope with drought is also a pressing issue that needs to be addressed. These shortcomings were fully exposed during the 1997-1998 transboundary haze event that seriously affected the South-East Asian countries, not only environmentally, but also socially and economically.

In Malaysia, apart from the National Security Council (NSC) Directive No. 20: The Policy and Mechanism for National Disaster Management and Relief, an executive directive of the Prime Minister enforced since 11 May 1997 and updated on 30 March 2012, currently there is no national coordination mechanism for El Niño in place, though the Malaysian Meteorological Department (MMD) does provide forecasting and report on its occurrence and inform relevant government departments. However, there is a need to further strengthen the national coordination mechanism for addressing drought, including the possible establishment of a National Drought Committee, which could complement the existing National Haze and Hot Weather Main Committee chaired by the Ministry of Natural Resources and Environment (NRE) participated by a number of related line ministries.

Drought management should not be a crisis management, reactive rather than preventive. It should be focused on risk reduction. In order to reduce drought risks in Malaysia, it is important to identify and minimise the factors that contribute to the vulnerability of Malaysia to drought. These factors could be related to policy, technical, technological (e.g., early warning system), environmental, social, economic, financial, cultural, as well as the institutional and human capacity for coping with and adapting to drought (this includes measures for prevention, preparedness and mitigation), among others.

It is also important to learn from past lessons. There are variations in vulnerabilities and impacts (environmental, social and economic) across various sectors and geographical locations. Based on past El Niño events, which may be classified as weak, moderate or strong, these variations could be analysed, studied and taken into account in dealing with the impacts of future El Niño events, including various measures for mitigating drought and adapting to drought.

There are various technical and technological measures are available to mitigate drought. These include both Integrated Drought Management and Integrated Water Resources Management, which are complementary to each other. While new technologies and research play an important role in strengthening practices to alleviate drought impacts to improve reliability and affordability, there are many simple technologies, such as rain harvesting and water conservations which can effectively help cope with drought. Effective policy measures should be implemented to reduce the adverse effects of drought.

There is a need for Malaysia to develop a framework with explicit focus on drought risk reduction to promote the understanding of natural and human-

induced drought, as well as the environmental, social and economic factors and policies that are vulnerable to drought. The framework may be based on the guiding principles and criteria of the Hyogo Framework for Action (HFA) for Disaster Risk Reduction 2005-2015 and the Sendai Framework for Disaster Risk Reduction 2015-2030; and specifically, the Drought Reduction Framework by United Nations International Strategy for Disaster Reduction (UNISDR) within the context of Malaysia. These global frameworks embrace the vision of building countries' and communities' resilience to disasters, including drought, and encourage nations to shift from reactive to anticipatory disaster risk management. The national drought risk reduction framework, taking into account potential synergies, would need to address institutional and implementation capacities.

Based on the framework on drought risk reduction, there is a need for Malaysia to develop a national policy on drought to address various vulnerabilities of drought-related disasters, with a view to minimise its impacts. Indeed, the lack of appropriate national policy and response measures based on the best available scientific data and information, and the lack of national capacity for drought risk reduction will have significant implications for sustainable development and for achieving the SDGs.

A national drought risk reduction policy should be an integral part of national climate change policy, which, in turn, should be an integral part of national sustainable development policy. A new policy for drought risk reduction must include the economics of drought. These include the cost of prevention versus the cost of mitigation, and the cost of action versus the cost of inaction. Indeed, ineffective policies for addressing drought could have significant implications for environmental, social and economic impacts and consequences. Thus, the costs of ineffective policies need to be considered and included in the economics of drought.

Drought risk reduction, like any other natural or human-induced disaster risk reduction, cannot be adequately implemented by the government and its agencies alone, because other stakeholders, such as communities, academia, civil societies and private sectors, are needed to play active roles. Inclusive public participation, based on a comprehensive communication and public awareness strategy targeted at various specific groups, is essential to ensuring the success of drought risk reduction at the national, state and local levels.

Some major initiatives toward implementing the priority areas of the HFA have been taken in Malaysia as evidenced by the development of National Action Plan for Disaster Risk Reduction. In terms of drought, the process of drought risk reduction and its mainstreaming into national climate change and development frameworks and policies must be comprehensive and participatory, involving a wide range of stakeholders such as national, state and local governments, community-based and civil society organisations, regional and sub-regional organisations, multilateral and bilateral international bodies, the scientific community, the private sector and the media.

It is proposed to establish a South-East Asia Network for Drought Risk Reduction (SEANDRR) to facilitate sub-regional collaboration for drought risk reduction, especially capacity development activities, so as to build resilience for drought risk reduction within the ASEAN members. This Network will complement and strengthen national capacity development programmes to enhance human and institutional capacities to better cope with future episodes of drought. It will be an important platform for sharing information on drought risk reduction, including scientific research, national programmes and policies, as well as good practices and lessons learned. Malaysia may take the lead to initiate the establishment of this Network perhaps under the auspices of the ASEAN Secretariat.

Research gaps

Contrary to the prediction in early 2014, including those by the leading scientific institutions in the world, the widely expected strong El Niño event was not developed by the end of the year (see Chapters 1 and 2). This demonstrates that there is still scientific uncertainty in terms of El Niño forecasting. It seems that many developing countries, including Malaysia, are closely following the forecasting of El Niño provided by leading scientific institutions in the world. Thus, it is also important to develop national scientific and research capabilities, to ensure the forecasting of El Niño is more relevant to the nation and local environment for better prevention, mitigation and adaptation measures.

Large knowledge gaps remain, particularly in terms of how the frequency of extreme El Niño and its teleconnection patterns over the Southeast Asian region will change in future warmer climate and vice versa. More research needs to be carried out on this issue. Further research also needs to be conducted on IOD and how it might affect Malaysia in future warmer climate. Malaysia also needs to develop its seasonal climate forecasting system that could incorporate changes from the Indian Ocean and the Pacific Ocean.

Research needs to be conducted to answer questions on how climate change will influence synoptic atmospheric circulation over the Southeast Asian region, affect the advection of transboundary pollutants in future haze episodes and how would the spatial and temporal variations of haze aerosols and ozone modify the regional radiative and convective processes during the haze episodes.

There is a need to further strengthen scientific and policy research on the environmental, social and economic impacts of the El Niño-induced drought to identify the factors, both climatic and non-climatic, that make Malaysia and Malaysians vulnerable to drought and the possible response measures that may be proposed to reduce their vulnerabilities and the risk to drought.

Past estimates of the environmental, social and economic impacts of the 1997/98 El Niño event were incomplete. Scientific research on the impacts of El Niño-induced drought or non-El Niño-induced drought on agricultural crops, biodiversity, terrestrial and marine ecosystems, and fisheries (e.g., especially on the migration of fishes and fish landing) have also been limited, including the spatial distribution of these impacts, and how these impacts could affect the national water, food and energy security. In view of the changing climate with increasing air and ocean temperatures, there is an urgent need to strengthen the scientific research in these areas.

In order for policy makers to make better decisions, extensive research is needed to assess the environmental, social and economic costs of prolonged drought induced by the past El Niño events, including the direct, indirect and economy-wide costs; the cost of prevention versus the cost of mitigation; as well as the cost of action versus the cost of inaction.

Answering the question on how could climate change affect the onset, magnitude, intensity and frequency of El Niño is needed to assess the links between climate change and El Niño. The Academy of Sciences Malaysia (ASM), with its extensive network of experts could play a useful role in facilitating similar scientific research in the country.

It is important to develop a national drought policy, that would be an integral part of the national climate change policy and the national sustainable development policy. A new policy for drought risk reduction must go beyond the reactive crisis

management. It must include the economics of drought that considers both the direct and indirect environmental, social and economic costs, as well as the economic-wide costs. The valuation of ecosystem services is an important component of the economics of drought. Drought leads to loss of biodiversity and land degradation. Thus, the economics of drought could be an integral part of the economics of climate change, biodiversity and land degradation. Much research is needed in the synergies between these areas.

Ineffective policies for addressing drought could have significant implications on environmental, social and economic impacts and consequences. Thus, the costs of ineffective policies should be considered and included in the economics of drought.

Data collection

In the future, all climatic, environmental, social and economic data relating to an El Niño event should be systematically collected by the relevant government agencies, perhaps in collaboration with ASM which has an extensive academic and scientific network, so as to facilitate research and analysis for future policy development.

Capacity development

Strengthening of human and institutional capacity, in a multidisciplinary manner, at the national, state and local levels are needed for drought risk reduction. Capacity development covers the scientific, technical, technological and policy aspects of drought risk reduction. Malaysia's higher education system and ASM have an important role to play in capacity development.

Chapter 1: General introduction

1.1 Background

Earlier in 2014, it has been predicted by various scientific sources that a strong El Niño event was likely to be developed during the year (NOAA, 2014; WMO, 2014). Because of this prediction, the Academy of Sciences Malaysia (ASM) has submitted a proposal to the Ministry of Science, Technology and Innovation (MOSTI), offering to undertake a study on the Social Impacts of El Niño, with a view to preparing a Position Paper for MOSTI's consideration based on the results of this study; and based on this Position Paper, MOSTI may then prepare a Cabinet Paper to advise the Government on appropriate actions to be undertaken for mitigating the impacts of the predicted strong El Niño event.

In order to undertake the above study, ASM has initiated the formation of a Task Force with wide representation from various ministries. The Task Force is entrusted with the study and the preparation of the Position Paper to be submitted to the ASM Science, Technology and Innovation Policy Advisory Committee (STIPAC). The ASM Council, at its 111th meeting held on 5 September 2014, has appointed Professor Dr Low Pak Sum as the Chair of the Task Force.

Letters were sent by the ASM Secretariat in early September 2014 to relevant ministries, inviting them to appoint representatives to participate in the first Task Force meeting which was held on 18 September 2014. In addition, individual experts from universities and the World Wildlife Fund Malaysia (WWF-Malaysia) were also invited to attend the meeting. The list of invitees is attached as Appendice 1. In particular, the following ministries have been contacted:

Ministry of Energy, Green Technology and Water (KeTTHA)
Ministry of Agriculture & Agro-Based Industry (MOA)
Malaysian Agricultural Research and Development Institute (MARDI)
Malaysian Meteorological Department (MMD)
National Hydraulic Research Institute of Malaysia (NAHRIM)
Ministry of Health (MOH)
Malaysian Palm Oil Board (MPOB)

The first Task Force meeting, chaired by Professor Dr Low Pak Sum and serviced by the ASM Secretariat, was participated by 13 members. However, by this time, it was clear that the original predicted strong El Niño event was not going to happen, while a weak event was expected to evolve over the following months. Thus, the Task Force members were of the view that instead of preparing the Position Paper for an El Niño event that was still uncertain, it would be better to focus on a more comprehensive and longer term study that will lead to an integrated national strategy and policy for coping with future El Niño events. In addition, both adequate time and financial resources are needed for such a comprehensive study if it is going to be useful.

Despite the recommendation of the Task Force members to focus on a longer term study, the ASM Secretariat is of the view that a short-term desk study would still be useful, and the results of this short-term study could be used for soliciting research funding for the longer term study. With the support and guidance of the Chair, the Outline of the short-term desk study was developed and shared with the Task Force members. The short-term study would only focus on the scientific understanding of El Niño and the impacts of

the 1997/98 strong El Niño event, to be used as a case study. This report is the outcome of the short-term study, and it could form the basis for a more comprehensive longer term study to be undertaken later.

1.2 Mandate

Contrary to the prediction in early 2014, the widely expected strong El Niño event had not been developed by the end of the year. By 8 January 2015, the overall atmosphere-ocean system remained El Niño Southern Oscillation (ENSO)-neutral, though most models predicted "the SST anomalies to remain at weak El Niño levels (3-month values of the Niño-3.4 index between 0.5°C and 0.9°C) during December-February 2014-15, and lasting into the Northern Hemisphere spring 2015". "If El Niño were to emerge, the forecaster consensus favors a weak event that ends in early Northern Hemisphere spring. In summary, there is an approximately 50-60% chance of El Niño conditions during the next two months, with ENSO-neutral favored thereafter"[1].(http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_jan2015/ensodisc.pdf)

Consequently, the original mandate provided by the ASM to the Task Force had to be modified. Instead of assessing the impacts or potential impacts of the expected strong El Niño event in 2014-2015, the Task Force has assessed the impacts of the strong 1997/98 El Niño event in Malaysia, with a view to drawing lessons learned from this case study.

However, while this report is being prepared in 2015, El Niño conditions were observed during February 2015. The atmospheric and oceanic features reflect "an ongoing and strengthening" El Niño during June 2015 (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_jul2015/ensodisc.pdf) and "a significant and strengthening" El Niño during July 2015 (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_aug2015/ensodisc.pdf). A strong El Niño continued from August 2015 to September 2015, which represented the peak of the event (http://www.esrl.noaa.gov/psd/enso/mei/#ElNino); and "strong and mature" during October 2015 (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_nov2015/ensodisc.pdf) and "has matured" during November 2015 (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_dec2015/ensodisc.pdf). The El Niño conditions remained strong until March 2016, but weakening in April 2016.

During April 2016, "sea surface temperature (SST) anomalies decreased across the equatorial Pacific Ocean, with near-to-below average SSTs recently emerging in the eastern Pacific". The Climate Prediction Center (CPC) of National Oceanic and Atmospheric Administration (NOAA) predicted in May 2016 that "La Niña is favoured to develop during the Northern Hemisphere summer 2016, with about a 75% chance of La Nina during the fall and winter 2016-17."[2]

However, the above development of the El Niño event in 2015/16 has not

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_jan2015/ensodisc.pdf)
[2] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.pdf

changed the objectives of this report. In any case, it will take time to assess the impacts of the 2015/16 El Niño event, which may be the focus of another ASM assessment report later, even though Section 2.7 does provide some information on the drought condition in West and East Malaysia induced by this 2015/16 El Niño event.

1.3 Objectives of the study

The objectives of this study are to:

(i) Discuss the scientific aspects of El Niño and its implications for Malaysia.

(ii) Use the 1997/98 strong El Niño event as a case study, assess the social and economic impacts of El Niño on various key sectors (e.g., water, energy, agriculture, biodiversity and health, etc.) in the country.

(iii) Identify and propose steps and measures that are required to be undertaken for addressing the adverse effects of El Niño; and make policy recommendations for reducing drought risk associated with future El Niño.

(iv) Based on the report of the study, ASM may prepare a Position Paper for MOSTI; and based on this Position Paper, MOSTI may prepare a Kertas Makluman for the Cabinet for consideration and for possible actions.

1.4 Scope of the study

This report is based on a comprehensive and critical review and analysis of existing literature and data collected from various sources, including data from the Department of Statistics Malaysia (DOSM): Official Portal, and Bank Negara Malaysia, and published peer-reviewed literature. However, newspaper reports are excluded. A number of authors, some of whom are Task Force members, contributed to this report.

1.5 Structure of the report

This report is divided into five chapters: Chapter 1 provides the background, mandate, the objectives and the scope of the study; Chapter 2 discusses the scientific understanding of El Niño, including its climatic implications for Malaysia; Chapter 3 focuses on the environmental, social and economic impacts of the 1997/98 El Niño event, which was one of the strongest events in recent history, on various key sectors (i.e., water resources, energy, agriculture, industries, marine and terrestrial ecosystems; health, tourism and education); Chapter 4 highlights the lessons learned from the case study of the 1997/98 El Niño, including the further strengthening of scientific research, and some of the technical, technological and policy measures that are required for coping with future El Niño events; and Chapter 5 provides the conclusions and some policy recommendations for further actions, including some important gaps for further research.

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Chapter 2: Scientific understanding of El Niño-Southern Oscillation (ENSO) and its climatic impacts in Malaysia and surrounding region

2.1 Introduction

The Earth's climate system is complex and inherently nonlinear. Due to this, in addition to the regular seasonal changes, the climate system is also characterised by the irregular natural variability of various timescales. Phenomena such as the Madden-Julian Oscillation (MJO), Indian Ocean Dipole (IOD), the El Niño – Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and North Atlantic Oscillation (NAO) are known examples of large-scale natural climate variability that exert impacts around the globe. In order to understand the impact of climate over a particular region or a locality, natural climate variability must be understood and quantified.

Malaysia is situated in the heart of the Southeast Asia region where its mean climate is governed by the Australian-Asian monsoon system. Figure 2.1 shows the annual cycles of precipitation at a number of stations in the west coast of Peninsular Malaysia, east coast of Peninsular Malaysia and East Malaysia (Sabah and Sarawak). During the northeast monsoon, rainfall amount reaches its maximum value in east coast of Peninsular Malaysia and Sarawak due to strong moisture convergence that is regulated by the cold surges and Borneo vortex circulations (Chang et al., 2005). During the southwest monsoon, Malaysia experiences its driest season as moisture brought by the southwest wind is blocked by the Barisan Mountains ranges over Sumatra. Interestingly, due to the blocking effect of the Titiwangsa mountain ranges, rainfall over west coast of Peninsular Malaysia also does not peak during the northeast monsoon period. In fact, the annual cycle for stations over the west coast of Peninsular Malaysia shows its double peaks during March-April-May (MAM) and September-October-November (SON), corresponding to the inter-monsoon periods. During inter-monsoon periods, wind is usually much weaker and such conditions allow local convection to flourish and this usually results in afternoon to late afternoon / evening heavy precipitation. Hence, the presence of mountain ranges and the synoptic circulation such as the Borneo Vortex, create various monsoonal climatic patterns over Malaysia.

Due to its unique location (i.e., situated in between two large oceans (Indian Ocean at its western side and Pacific Ocean at its eastern side), Malaysian climate is also characterised by variability associated with climate phenomena induced by

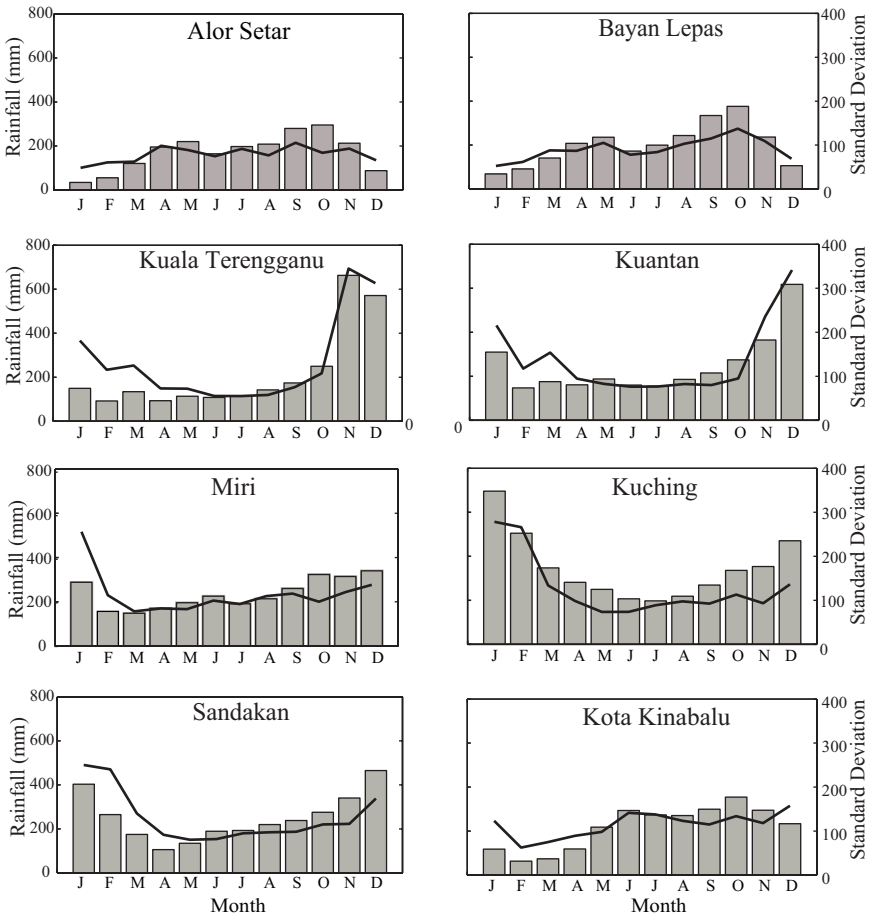


Figure 2.1 Annual cycles of rainfall at several locations in the west coast of Peninsular Malaysia, east coast of Peninsular Malaysia and East Malaysia (Sabah and Sarawak)

changes in these oceans. On the intra-seasonal timescales of 20-60 days, Malaysian climate is regulated by the MJO (Jamaludin, 2014). MJO is characterised by eastward propagation of alternating large-scale enhanced and suppressed convective systems from the Indian Ocean to Pacific Ocean and these often cause drought and flood over the Maritime Continent region, including Malaysia. The prolonged drought event experienced during March – April 2014 over Peninsular Malaysia can be linked to this phenomenon. Malaysia is also largely affected by the ENSO phenomenon. However, the severity of impacts varies seasonally and spatially (Tangang 2001; Tangang and Juneng, 2004; Juneng and Tangang, 2005; Salimun et al., 2014a). A recent study by Arif (2014) showed that most droughts episodes in Malaysia are associated with El Niño. Tangang et al. (2010) indicated that Malaysia does not only suffer from drought but also poor air quality due to the haze episode induced by the drought condition. The impacts of IOD on the Malaysian climate is less clear but a recent study Salimun (2014) seems to suggest that IOD could enhance the severity of a drought episode if it co-occurs with an El Niño episode.

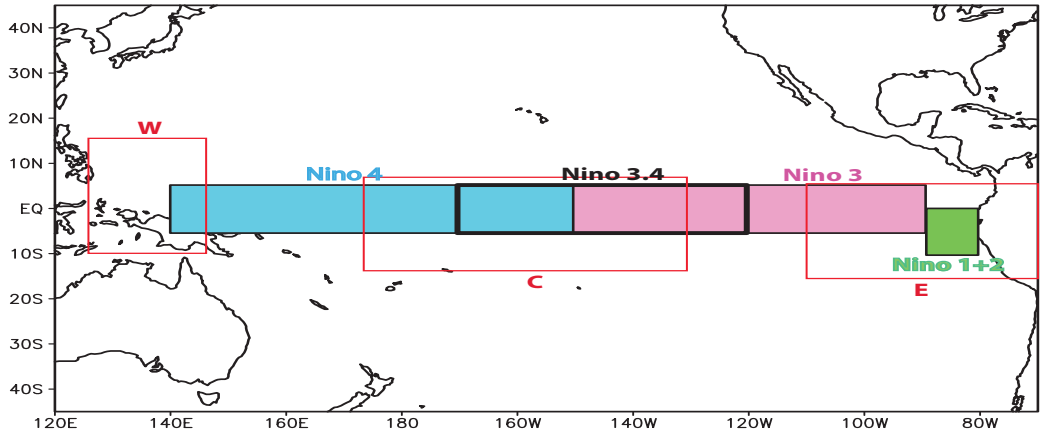


Figure 2.2 The regions used to define El Niño and El Niño Modoki indices

Extreme events can also occur because of interactions of these phenomena. For example, Tangang et al. (2008) attributed the occurrence of the widespread flood at the southern region of Peninsular during end of December 2006 and early January 2007 to the complex interaction between strong cold surges, Borneo Vortex, MJO and IOD. In addition to natural variability, Malaysian climate also experiences long-term changes associated with global climate change (e.g. Tangang et al., 2012; Tangang et al., 2013; Kwan et al., 2014). Malaysia has experienced significant increase of mean temperature and extreme events since the middle of 20th century (Tangang et al., 2007; Salinger et al., 2014). Due to the prominence and the severity of impacts it can exert, this Chapter provides an assessment of scientific knowledge of the ENSO phenomenon and its impacts on the Malaysian climate based on published literatures and other relevant sources.

2.2 The ENSO phenomenon and its different types of variations

The ENSO phenomenon is the most dominant inter-annual mode of oscillation associated with the coupled ocean-atmosphere interaction in the tropical Pacific Ocean. The phenomenon generated a great interest from the scientific community in the early 1980s where extensive literature can be found describing its characteristics, mechanisms and impacts. Wang and Picaut (2004) provided a comprehensive review of the understanding of ENSO physics. The coupled atmosphere-ocean system oscillates to produce warmer ocean temperature anomaly in the eastern tropical Pacific Ocean and if the anomaly reaches more than 0.5°C, the coupled system may enter an El Niño condition. The typical index used to monitor this is the so-called Niño3.4 Index, which is the average SST anomaly of 5°S-5°N, 170°W-120°W (Figure 2.2). The SST anomaly could also swing into negative values where the coupled system may enter into a La Niña state. Moreover, since this is a coupled atmosphere-ocean phenomenon, warming (cooling) in the eastern Pacific Ocean occurs in conjunction with rising (decreasing) surface pressure

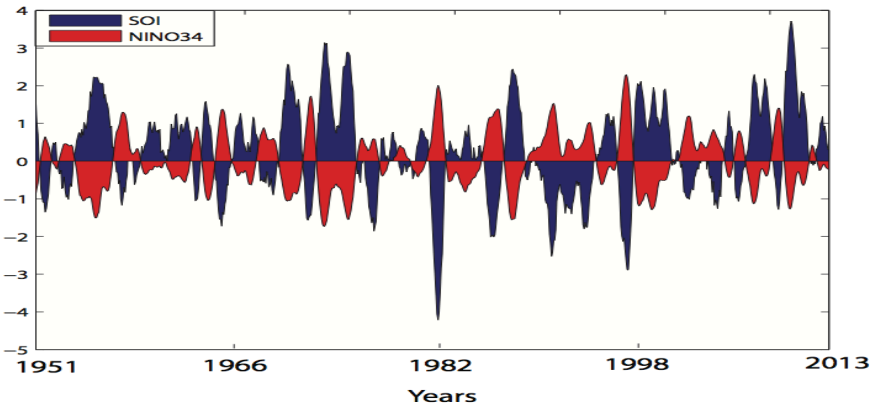


Figure 2.3 The Niño3.4 and SOI indices indicating the coupled nature of the ocean and atmosphere in the tropical Pacific Ocean. The values in the Y-axis represent standardised values

over eastern Pacific Ocean. Tahiti is usually taken as a reference point for this surface pressure changes. Since the changes in the coupled system is basin-wide, increasing (decreasing) surface pressure over the eastern side of the Pacific Ocean is matched by a decreasing (increasing) surface pressure over the western side of the Pacific Ocean, in which Darwin is taken as a reference point. The pressure swings between Tahiti and Darwin is known as the Southern Oscillation and the index used to represent this is the Southern Oscillation Index (SOI). On the first order, the SOI can be taken as the opposite of Niño3.4 Index (Figure 2.3). Although the discovery of El Niño and Southern Oscillation occurred differently, it was in the 1980s that the scientists realised that the two phenomena are coupled and hence the terminology ENSO was used to represent the coupled tropical Pacific Ocean oscillation (e.g. Neelin, 2012). The warm phase of ENSO is El Niño while the cold phase is La Niña.

The oscillation in the atmosphere-ocean coupled system in the tropical Pacific Ocean does not only involve changes in the surface pressure and ocean surface temperature but the entire components of the system. These include changes in the ocean temperatures at depths, equatorial and off-equatorial thermocline, sea level, surface winds, tropical convection centres and the Walker Circulation. Such changes in the multi-components of the tropical Pacific Ocean system can be visualised in Figure 2.4. During an El Niño event, the increase of SST and decrease of surface pressure in eastern region of the tropical Pacific Ocean results in weakening of the trade winds. This weakening of trade winds creates domino effects where the east-west sea level gradient can no longer be maintained and consequently, warm surface water from the west surges to the east to reinforce the initial warming. This also triggers Kelvin waves that travel eastward that further depress the thermocline in the eastern part of the Pacific Ocean. Deeper than normal thermocline and coupled with weakened or the absence of upwelling process reinforces further warming in eastern Pacific Ocean and subsequent development of the El Niño. Further warming in eastern Pacific Ocean and eastward advection of surface warm

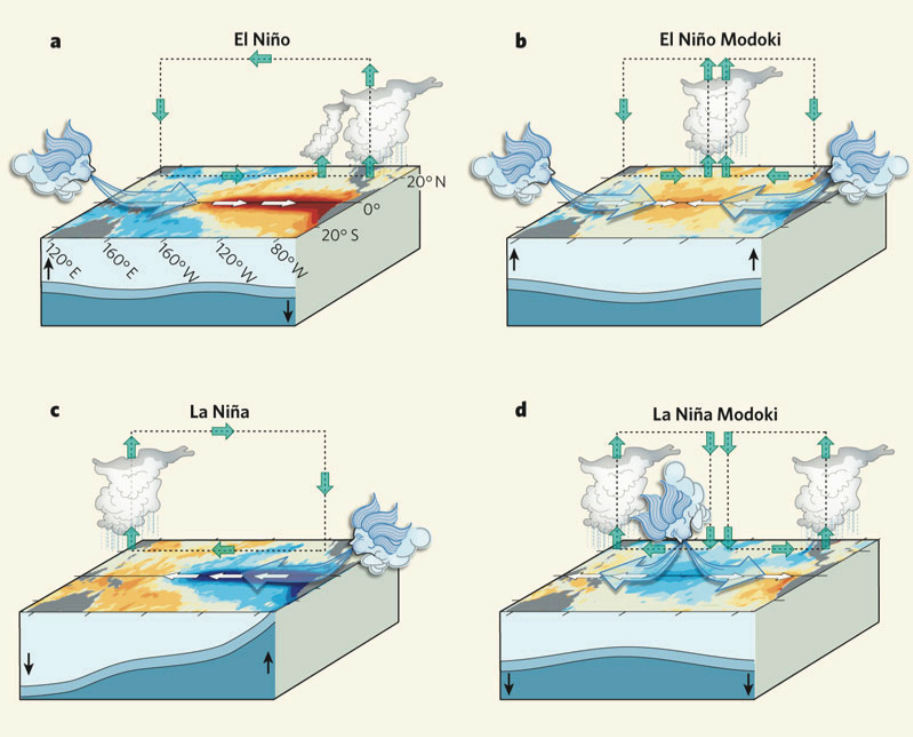


Figure 2.4 Schematic illustrations of conventional El Niño and La Niña and El Niño and La Niña Modoki (Ashok and Yamagata 2009; Figure 2)

water from the west also causes the migration of the high surface atmospheric pressure centre from over the Maritime Continent to the central Pacific Ocean. This changes the structure of the Walker Circulation from one cell circulation into two-cell circulation. The condition over the Maritime Continent changes from a "rising" branch to a "subsiding" branch of the Walker Circulation. The rising branch that coincides with a region of anomalous convective activities migrates to the central Pacific Ocean leaving the Maritime Continent with much drier conditions and stable atmosphere. This explains why Maritime Continent experiences drought condition during an El Niño event.

The coupling between the ocean and atmospheric components described above basically follows the Bjerknes feedback mechanisms. Similar but opposite feedback responses can be argued for a La Niña event. However, the subsequent transition of the state of the coupled system from an El Niño state to normal or La Niña state requires delayed response that is provided by the generated off-equatorial Rossby waves that propagate westward. Interestingly, these off-equatorial Rossby waves are triggered by the downwelling Kelvin waves that arrived at the east coast. Once such waves reach the west coast, the energy is used to trigger upwelling equatorial Kelvin waves that propagate back to the east and eventually lift the thermocline to its normal position and ends the El Niño condition. These delayed responses through off-equatorial Rossby waves are the essence of the Delayed ENSO Oscillator theory (e.g.

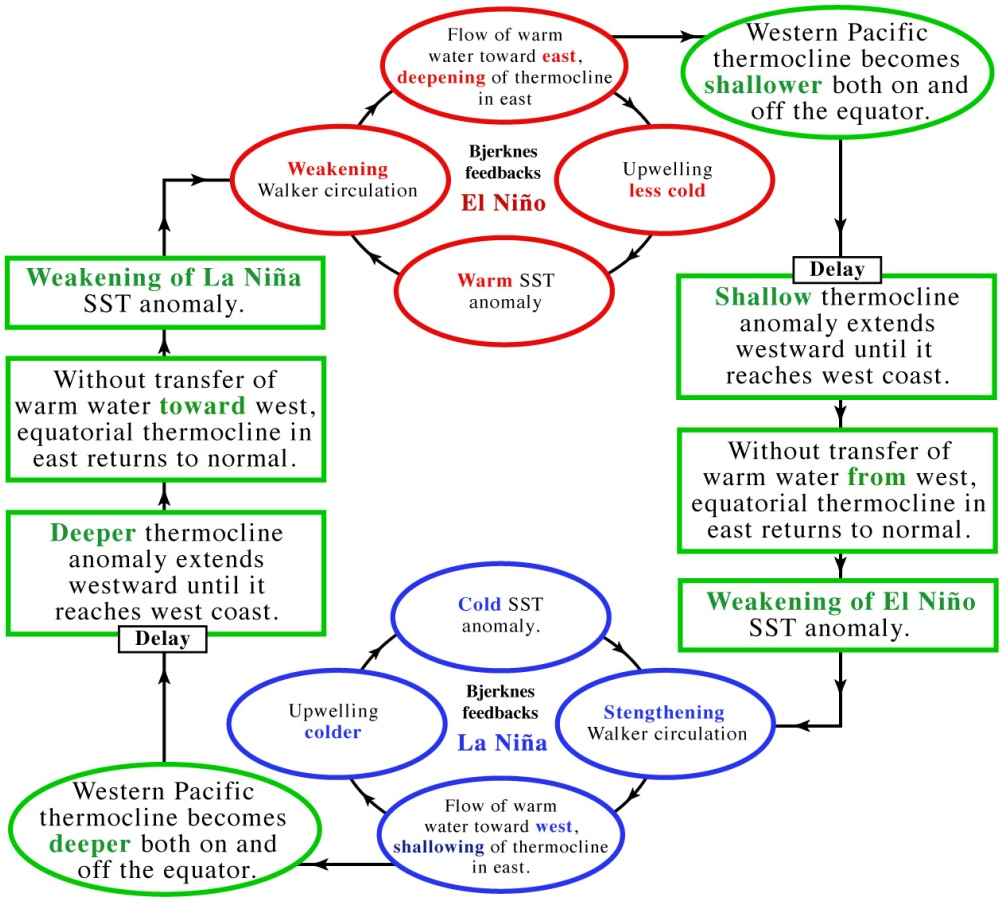


Figure 2.5 Schematic illustration of ENSO Delayed Oscillator (Neelin, 2012; Figure 4.14)

Graham and White, 1988; Suarez and Schopf, 1988; Battisti and Hirst, 1989). The complete cycle of the coupled system is schematically presented in Figure 2.5. However, there are other theories put forward to explain the termination of an El Niño state (Wang and Picaut, 2004). These include the recharge oscillator (Jin, 1997), the western Pacific Oscillator (Weisberg and Wang, 1997) and the advective-reflective oscillator (Picaut et al., 1997). Most of these theories outline regular and never-ending oscillation from El Niño state to a La Niña state and vice versa. In reality, however, the oscillation is irregular but seasonally phase-locked with periodicity of about four years. The seasonal cycle contributes to the irregularity and phase-locking of ENSO while the intra-seasonal variability causes both variability and irregularity of ENSO (Wang and Picaut, 2004). Hence, an El Niño event may not necessary be generated from the previous La Niña but can be triggered by "external" factor. An "external" factor that is usually attributed to El Niño initiator is the intra-seasonal variability (ISV) that has higher frequencies than ENSO. Westerly wind burst (WWB) in the western region of the Pacific and the MJO are parts of the ISV. WWB and MJO generate pulses of downwelling Kelvin waves that propagate to the east depressing the thermocline and to initiate the El Niño development.

There is also a tendency for the coupled atmosphere-ocean system to evolve different with the maximum warming located in the central region

rather than eastern part of the Pacific Ocean. This coupling is recognised as a different mode of the tropical Pacific Ocean coupled system and known as the ENSO Modoki (Ashok et al., 2007). The warm (cold) phase of this mode of coupling is El Niño (La Niña) Modoki. The ENSO Modoki oscillation is monitored using the El Niño Modoki Index (EMI) = C - 0.5 x (E + W)). The letters in the equation represent the area-averaged SST anomalies over Regions C (165ºE-140ºW, 10ºS-10ºN), E (110ºW-70ºW, 15ºS-5ºN), and W (125ºE-145ºE, 10ºS-20ºN), as indicated in Figure 2.2. The typical coupling with warming at the eastern region of the Pacific Ocean is referred as conventional ENSO with conventional El Niño (La Niña) as its warm (cold) phase. Figure 2.4 shows schematically the different patterns of conventional ENSO and ENSO Modoki. Other terminologies have been used for the central Pacific warming such as the central Pacific El Niño (Kao and Yu, 2009) and warm pool El Niño (Kug et al., 2009). The ENSO Modoki becomes prominent after the 1980s due to the changes in the subsurface ocean temperature distribution in the tropical Pacific Ocean (Ashok et al., 2007; Kao and Yu, 2009; Kug et al., 2009). The different positions of heating in the tropical Pacific Ocean induce different perturbations to the Walker Circulation and exert different impacts and climate anomalies around the world. In Malaysia and the greater Southeast Asia region, conventional ENSO and ENSO Modoki exert different impacts (Tangang 2001; Tangang and Juneng, 2004; Juneng and Tangang, 2005; Feng et al., 2010; Tangang et al., 2012; Salimun et al., 2014a). Further discussion on this will be provided in the sections below.

2.3 Conventional El Niño and El Niño Modoki: Their different evolutions and characteristics

Table 2.1 shows the recorded conventional El Niño and El Niño Modoki occurrences since early 1950s (Salimun et al., 2014a). Typically a conventional El Niño begins during in May, peaks towards the end of the year or early months of the following year and subsides in the following spring season. Conventional El Niño events occur in different strengths with the 1997/98 El Niño was recognised as the strongest El Niño ever recorded (Figure 6). During its peak, the SST anomaly in eastern coast of the Pacific Ocean reached 5ºC warmer than normal. Figure 2.7 shows the SST anomaly during several phases of the 1997/98 El Niño. As can be seen during the mature phase, the warm anomalies of -SST extend eastward as far as the dateline. Since the establishment of the Tropical Atmosphere Ocean (TAO) Array in 1994 under the Tropical Ocean-Global Atmosphere (TOGA) programme year (e.g., McPhaden et al., 1998) (Figure 2.8), scientists have been able to monitor the subsurface temperature of the tropical Pacific Ocean and the condition of the thermocline in almost real-time. Figure 2.9 provides the sequence of subsurface temperature anomaly in the equatorial Pacific Ocean beginning in January 1997 until May 1998. During January 1997, the surface condition at the eastern part of the Pacific Ocean was still normal. However, the condition at the subsurface proved different with the existence of warmer anomalies of greater than 3ºC centred at depth of about 150m, indicating that the thermocline was depressed. This is the signature of downwelling Kelvin waves travelling eastward and depressing the thermocline

Table 2.1 The list of conventional El Niño and El Niño Modoki years used for composite analysis. The identification of conventional El Niño and El Niño Modoki is based on the CDC and Ashok et al. (2007)
*The letters W, M, S, and VS correspond to weak, moderate, strong and very strong El Niño, respectively. There is no known classification of El Niño in the literature

Conventional El Niño	El Niño Modoki
1957/58(S)	1979/80
1963/64(M)	1986/87
1965/66(S)	1990/91
1968/69(M)	1991/92
1972/73(S)	1992/93
1976/77(W)	1994/95
1977/78(W)	2002/03
1982/83(VS)	2004/05
1987/88(M)	
1997/98(VS)	

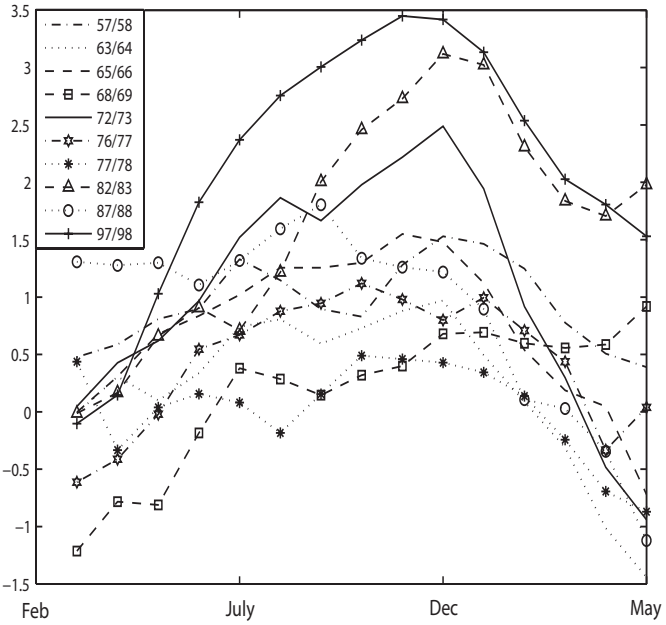


Figure 2.6 The values of Niño3 index of various El Niño highlighted in Table 2.1 for a period of March of an El Niño year to May of the following year. During the 1997/98 El Niño, Niño3 SST Anomalies attained the highest values among all the episodes. Unit is in °C

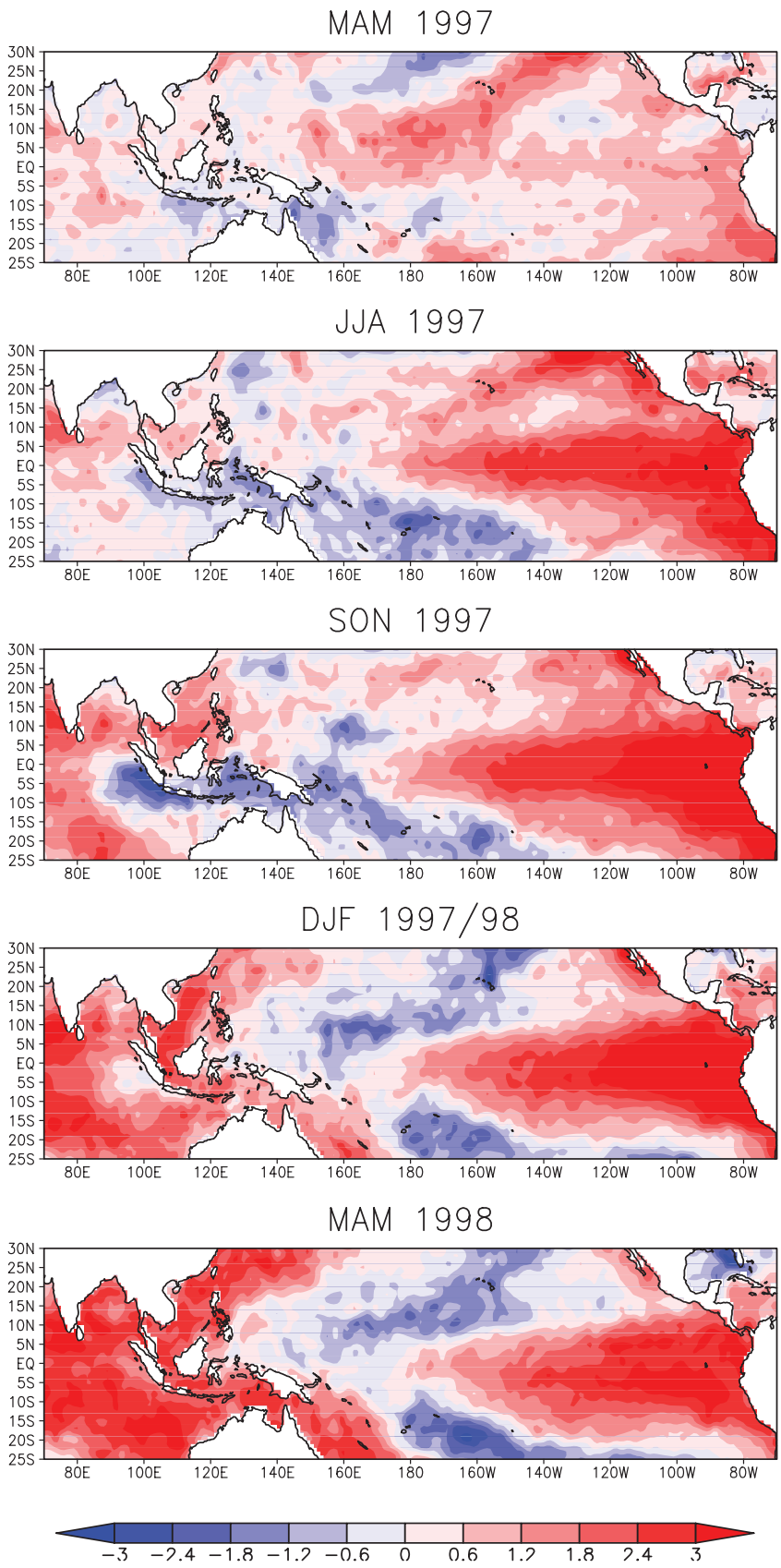


Figure 2.7 Seasonal evolution of SST anomaly during the 1997/98 El Niño. Unit is in °C

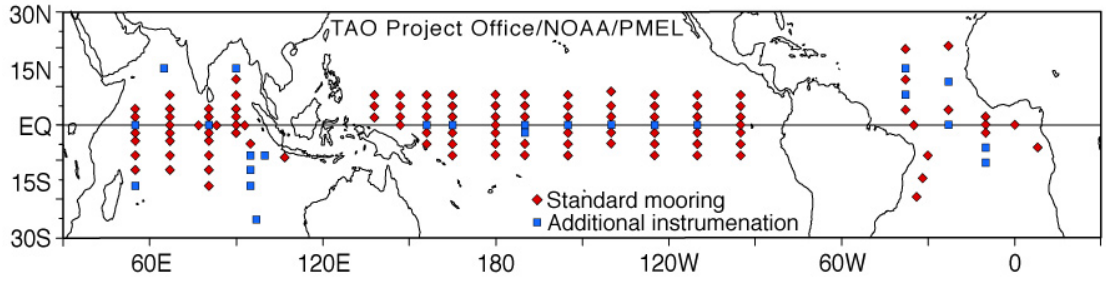


Figure 2.8 The global tropical moored buoy array. Those arrays in the tropical Pacific Ocean are the original arrays of the TAO Project meant to monitor ENSO development (Neelin, 2012; Figure 4.7)

along the way. By April 1997, the Kelvin waves arrived at the east coast and subsequently initiated further development of the El Niño 1997. By May 1997, sea surface at the eastern region began to warm and the SST anomaly continued to increase in the next couple of months and expanded westward until it reached the maximum values in January 1998. By March 1998, it began to weaken and the El Niño was considered ended in May 1998. It is also interesting to note that during September 1997, a negative anomaly of subsurface temperature anomaly of lower than -4°C began to appear and centred at 150m – 200m depth and 160°E. This condition signalled the uplifting of the thermocline higher than its normal position. This uplifting was due to the upwelling Kelvin waves as described in the Delayed ENSO Oscillator Theory and eventually terminated the 1997/98 El Niño. On the first order, the evolution of a conventional La Niña can be taken as opposite to that of the conventional El Niño. In fact, the 1997/98 conventional El Niño was immediately followed by the 1998/99 La Niña (Figure 2.10).

The evolution of El Niño Modoki events is different from that of the conventional El Niño. While the warmest SST anomalies is located at the eastern Pacific Ocean during the conventional El Niño, the warmest SST anomalies during El Niño Modoki is located at the central of Pacific Ocean and sandwiched by cooler SST anomalies on its east and west (Figure 2.4). The condition of the SST anomalies during El Niño Modoki is associated with more westward and smaller spatial scale westerly anomalies which centred in the equatorial central-to-western Pacific (Kao and Yu, 2009; Kug et al., 2009). Meanwhile, significant easterly anomalies also appear over the tropical eastern Pacific during the El Niño Modoki. The convergence of the equatorial westerly anomalies induces downwelling Kelvin waves while the equatorial easterly anomalies that induce downwelling Rossby waves deepen the thermocline in the central Pacific to produce the El Niño Modoki (Ashok et al., 2007). After an El Niño Modoki reaches its mature phase, the anomalous easterlies as well as the equatorial upwelling in the eastern Pacific are further strengthened. Together, the excited downwelling Rossby waves that propagate further west and the weakening westerlies in the western Pacific terminate the El Niño Modoki events. Figure 2.11

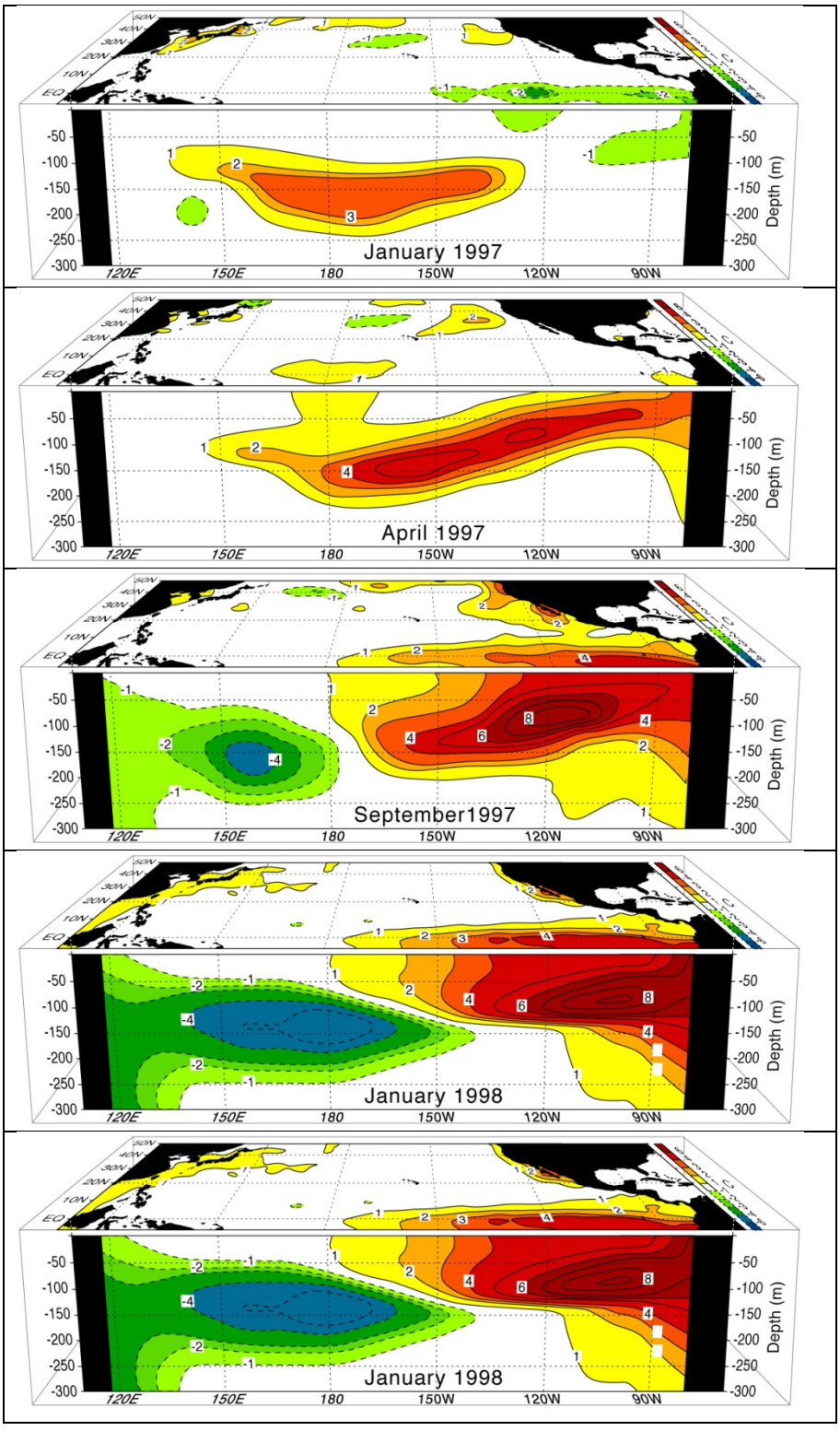


Figure 2.9 The evolution of subsurface and surface temperature anomalies based on TAO array data during the 1997/98 El Niño (Neelin, 2012; Figure 4.8)

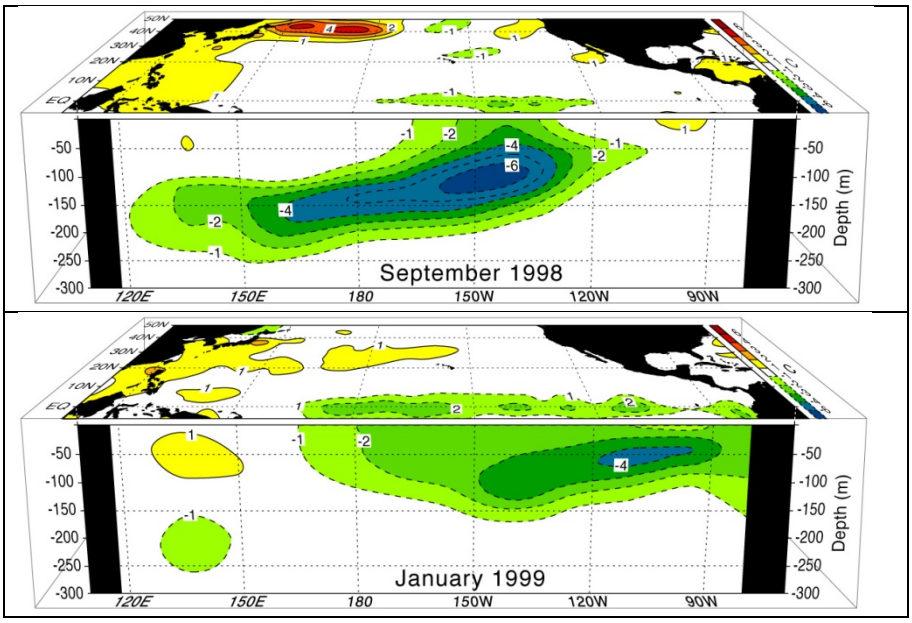


Figure 2.10 Evolution of subsurface and surface temperature anomalies during the La Niña 1998/99 (Neelin, 2012; Figure 4.9)

indicates the EMI values for El Niño Modoki listed in Table 2.1. Clearly there are differences from one episode to another. The spatial patterns of the SST anomalies during the 1990/91 El Niño Modoki are also different from the typical warming patterns of a conventional El Niño (Figure 2.12)

2.4 ENSO predictability and prediction

The number of research activities on ENSO began to increase in the early 1980s, especially after the strong 1982/83 and surged in the 1990s. The research activities were not just focusing on the understanding of ENSO based on observation and theoretical approaches but also on its predictability. Models have been developed to forecast ENSO development. The Zebiak-Cane Model, an intermediate coupled model, was developed in 1986 and considered a pioneer and a milestone in ENSO forecasting (Zebiak-Cane, 1987). The development of coupled models for ENSO forecasting continues until recent years. A number of statistical models have also been developed. An example of such model is the UBC NNET, which is an ENSO statistical prediction model using neural network developed by the first author in fulfilment of his PhD at the University of British Columbia, Vancouver, Canada (Tangang et al., 1997; Tangang et al., 1998a; 1998b). This is one of the models used by the International Research Institute for Climate and Society, Columbia University in its ENSO forecasts[3]. In addition, hybrid models, i.e. a combination of dynamical and statistical models have

[3] http://iri.columbia.edu/our-expertise/climate/forecasts/enso/

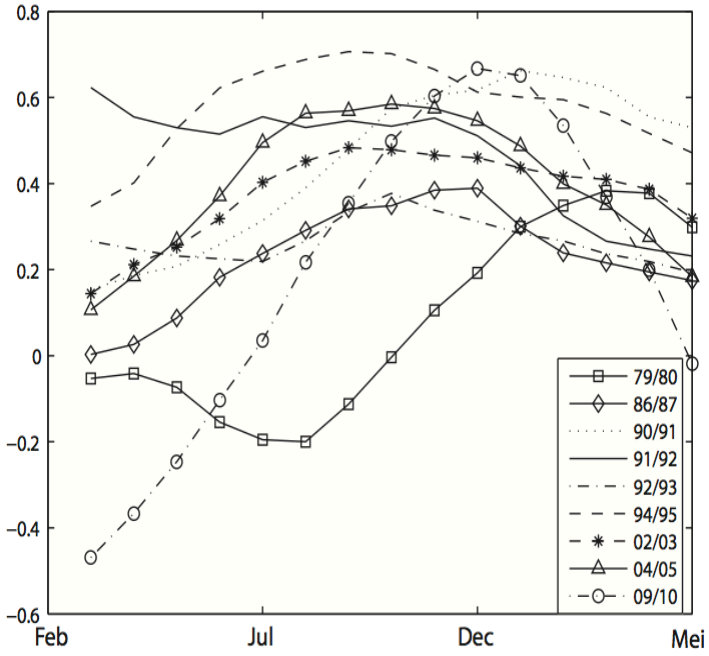


Figure 2.11 The EMI values for El Niño Modoki episodes. Unit is in °C

also been developed. Latif et al. (1998) provided a complete review of ENSO models developed in the 1980s and 1990s. Generally, ENSO models (both dynamical and statistical) provided forecast skills higher than persistence at 6 – 12 months lead-times (Latif et al., 1998). In a more recent paper, Barnston et al. (2012) compared the performances of 23 ENSO models (15 dynamical and 8 statistical models, including UBC NNET) and concluded that for a period of recent decades, the dynamical models outperformed the statistical models. Overall, research and development activities since the early 1980s contributed to a much better understanding of ENSO and development of a variety of forecasting models. With the latest atmospheric and oceanic observations in the Pacific and latest forecasts of various ENSO models, the CPC of the NOAA of the United States of America regularly produces ENSO advisories in Weekly ENSO Update and Monthly Climatic Diagnostics Bulletin[4]. These advisories are extremely useful especially for countries affected by ENSO events in monitoring ENSO latest development and forecasts. Malaysia should benefit from such products and should incorporate them in monitoring ENSO impacts in this country.

2.5 Conventional ENSO and ENSO Modoki impacts on climate in the Malaysia and the Southeast Asian region

The impacts of conventional ENSO and ENSO Modoki events in Malaysia and the South-East Asia region are mainly tele-connected through changes in atmospheric

[4] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/

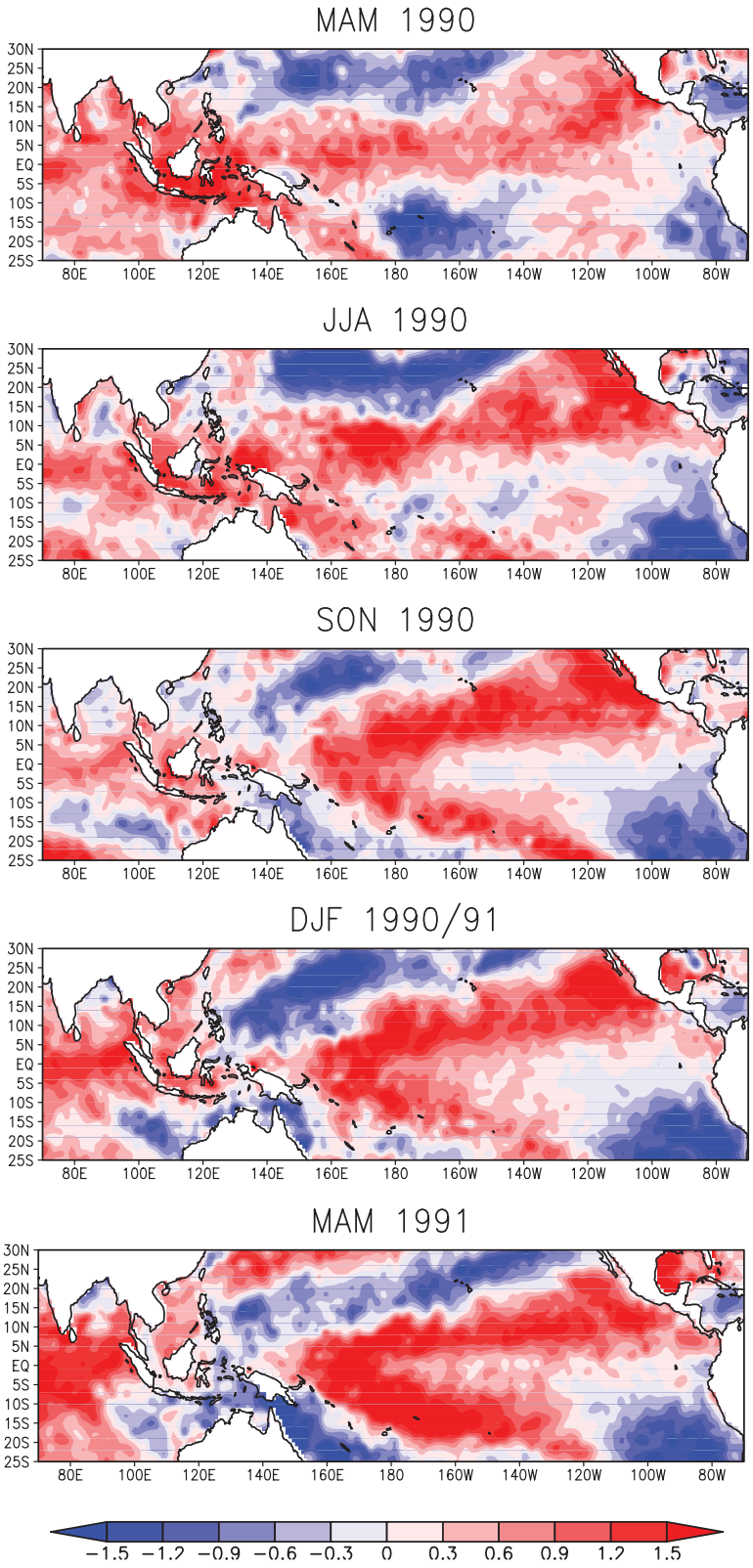


Figure 2.12 Seasonal evolution of SST anomalies of El Niño Modoki 1990/91. Unit is in °C

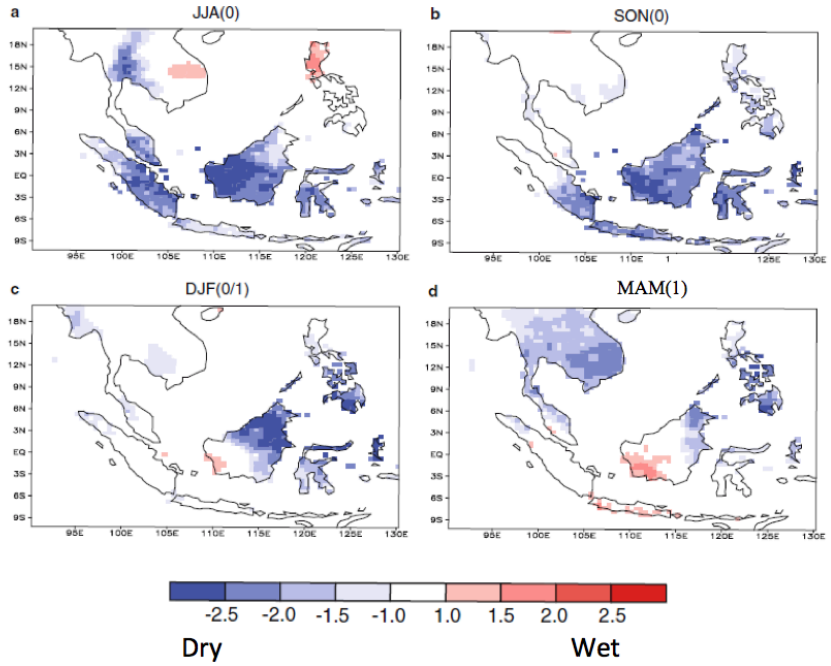


Figure 2.13 The spatial patterns of the most dominant extended empirical orthogonal function (EEOF) mode of the Southeast Asia rainfall anomalies at different seasons throughout the ENSO evolution period. For an El Niño event, the negative values are associated with deficit rainfall. This mode correlates well with Niño3.4 index and explains about 20% of the variance (Juneng and Tangang, 2005; Figure 1)

circulation and subsequently through changes in regional air-sea interactions. During the occurrence of a conventional El Niño event, Malaysia and the Southeast Asia region generally experience drought condition. Figure 2.13 shows the most dominant mode of the extended empirical orthogonal function (EEOF) of precipitation anomaly over the Southeast Asia region (Juneng and Tangang, 2005). The temporal coefficient of this mode is highly correlated with ENSO occurrences. Interestingly, as shown in Figure 2.13, the region that experiences rainfall deficit or drought condition does not only vary seasonally but also spatially. This can be considered as the typical patterns of impacts of conventional El Niño over this region. During June-July-August of the El Niño year (JJA(0)), Peninsular Malaysia, Sumatra and southern Borneo experience drought conditions, which are often associated with severe haze episodes (Tangang et al., 2010). During September-October-November (SON(0)), southern parts of Sumatra, Java and the entire Borneo experience drier-than-normal condition. During this period, the condition over Peninsular returns to normal. However, haze episodes could still develop during this period due to the dry condition over Sumatra and Borneo. During December through January and February of the following year (DJF(0/1)), the drought condition persists over northern Borneo and southern Philippines but over other regions (Peninsular Malaysia, Sumatra, southern Borneo), the conditions return

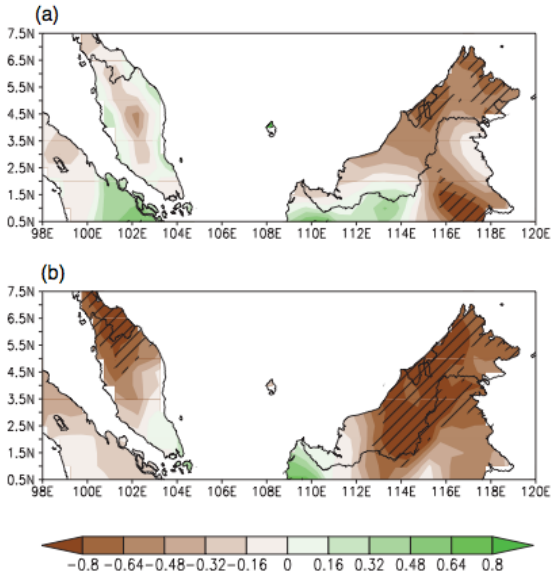


Figure 2.14 The composite of December-January-February rainfall anomalies for a) Conventional El Niños, b) El Niño Modoki. Hatched region indicates significant at 95% level. Unit is mm month^{-1} (Salimun et al., 2014a; Figure 2)

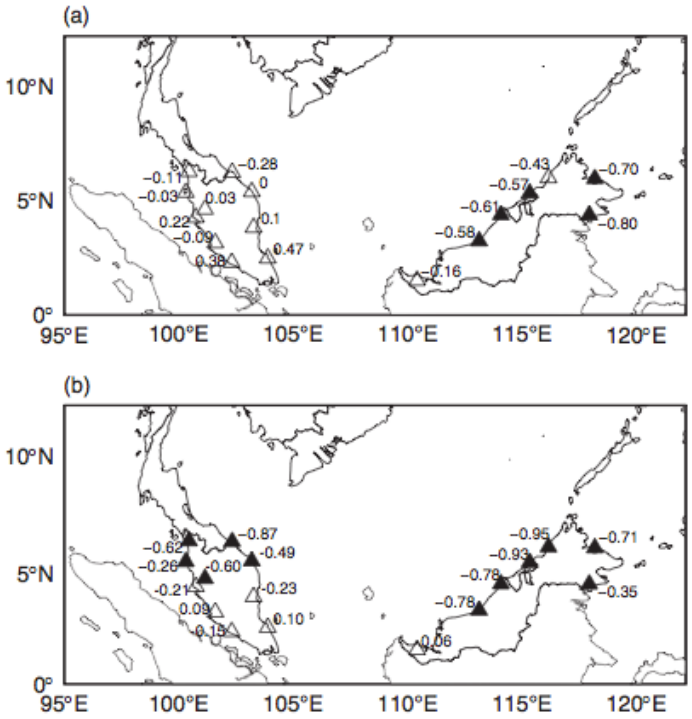


Figure 2.15 As in Figure 2.14 except the composites were based on station data. Dark triangles indicate significance at 95%. Unit is mm month^{-1} (Salimun et al., 2014a; Figure 3)

to normal. During the ending phase of a conventional El Niño, only the northern tip of Borneo, southern Philippines and Indochina regions are affected.

Throughout the sequence from the early development of a conventional El Niño until the ending phase, the coverage of drier-than-normal area appears to evolve in north-eastward direction. Such a north-eastward evolution is actually associated with the regional air-sea interactions induced by the El Niño perturbation over this region (Juneng and Tangang, 2005). Such perturbation induces anomalous anti-cyclonic circulations over the south-eastern Indian Ocean (SIO) during SON(0) and over the western North Pacific during DJF (0/1) (Wang et al., 2003). The strengthening and weakening of these anti-cyclonic circulations modulate north-eastward evolution of the drier-than-normal condition over the South East Asia region. Hence, the regional air-sea interaction is important in communicating the local and regional impacts of a conventional El Niño. In conjunction with this, monsoonal winds strengthen during JJA(0) while weaken during DJF(0/1) (Juneng and Tangang, 2005). The SST anomaly in South East Asia regional seas (particularly the South China Sea) tends to lag by at least a season compared with the eastern Pacific anomaly (Juneng and Tangang, 2005). During JJA(0), the SST anomaly in the South China Sea still appears normal but begin to warm in subsequent seasons. In addition, surface waves in the South China Sea are also influenced by El Niño occurrences (Mirzaei et al., 2013).

The impacts of El Niño Modoki on Malaysian rainfall differ from that of the conventional El Niño (Salimun et al., 2014a; Salimun, 2014). This is particularly striking during DJF(0/1) where Peninsular Malaysia also tends to be significantly influenced during El Niño Modoki. Hence, during DJF(0/1) of an El Niño Modoki, both Sabah-Sarawak and Peninsular would experience drier-than-normal condition (Figures 2.14 and 2.15). While the impact of El Niño tends to cause drier-than-normal condition over the region, the La Niña occurrences cause the opposite i.e. wetter-than-normal conditions (Tangang and Juneng et al., 2004; Juneng and Tangang 2005). This is due to the strengthening of trade winds over the Pacific Ocean resulting in anomalous convergence of moisture in the South-East Asia region. In such a situation, the probability of flood occurrences increases. Generally, the evolution of La Niña related anomalies over the region can be viewed as opposite to that of the El Niño.

The ENSO phenomenon does not only affect the rainfall distribution but surface air temperature also. Table 2.2 shows the maximum surface air temperatures (Tmax) recorded during conventional El Niño and El Niño Modoki events at a number of stations throughout the country. Generally, the Tmax increases during both conventional El Niño and El Niño Modoki. During an El Niño event, because of stable atmosphere and lack of clouds, insolation over Malaysia usually increases. This increase in heat flux increases surface air temperature, which in turn raises the energy demand for cooling. Tangang et al. (2007) analysed the trend and variability of 42 years (1961-2002) surface air temperature data of 11 measurement stations through Malaysia. The study concluded that the surface air temperature over Malaysia had

Table 2.2 The Tmax recorded during conventional El Niño and El Niño Modoki events at some selected stations throughout the country. Also shown is the mean Tmax for each station. Unit is °C

Station Name	Normal Tmax	El Niño 1968/69	El Niño 1972/73	El Niño 1976/77	El Niño 1977/78	El Niño Modoki 1979/80	El Niño 1982/83	El Niño Modoki 1986/87	El Niño 1987/88	El Niño Modoki 1990/91	El Niño Modoki 1991/92	El Niño Modoki 1994/95	El Niño 1997/98	El Niño Modoki 2002/03	El Niño Modoki 2004/05
Bayan Lepas	31.4	32.9	33.1	32.2	33.0	33.0	32.4	32.4	32.9	32.3	32.4	32.1	32.7	33.9	33.0
Chuping	32.7					36.0	36.0	34.8	35.4	35.2	35.5	34.4	34.8	36.0	35.2
Ipoh	33.0	34.3	33.8	34.0	34.2	34.4	33.9	34.2	35.0	34.4	34.7	33.9	34.1	35.4	33.8
Kuantan	31.7	32.3	33.1	33.0	33.2	33.8	33.1	33.6	33.5	33.4	34.0	33.0	34.8	33.8	34.5
Mersing	30.7	33.0	32.8	31.0	31.7	32.2	31.4	32.3	31.9	32.3	31.5	31.4	33.3	32.6	33.4
Kota Kinabalu	31.5	31.2	31.9	31.5	31.9	32.1	32.9	32.9	32.8	32.6	32.8	32.8	32.8	33.6	34.0
Kuching	31.6	32.7	33.7	33.3	33.3	33.9	33.6	33.0	33.3	33.3	32.9	33.0	33.7	33.1	33.5

Source: Tangang et al. (2007)

increased during the 42 years in most of the stations at rates higher than the rate of increase of global surface air temperature estimated by the Intergovernmental Panel on Climate Change (IPCC). Interestingly, 60-80% of inter-annual variability of surface air temperature over Malaysia was due to ENSO fluctuations. During an El Niño, depending on season and location, the increase in mean temperature can be as high as 2°C. However, unlike rainfall, the impacts of ENSO on surface temperature appear to have much less spatial and temporal variability.

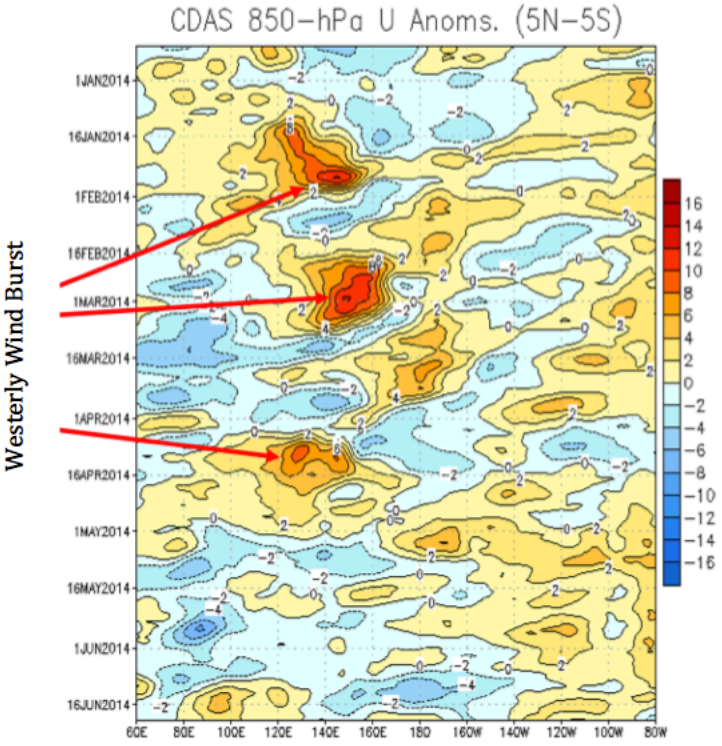


Figure 2.16 The HovmÖller plot of zonal 850 hPa wind anomalies, averaged over 5°S-5°N, over the tropical Indian-Pacific Ocean from January to mid-June 2014. Unit is in ms^{-1}. The figure is provided by the CPC NCEP (National Centers for Environmental Prediction) NOAA

2.6 The predictability of Malaysian anomalous rainfall associated with ENSO

Due to the modulation of ENSO on rainfall over Malaysia, some levels of predictability of rainfall anomaly can be expected from ENSO signals. This issue has been investigated by a number of papers. Juneng and Tangang (2008) evaluated the skills of forecasting of rainfall anomaly over Malaysia by using the canonical correlation analysis (CCA) technique to model the relationship between rainfall anomaly and ENSO related indices. This study indicated useful skills (→0.5 correlation) for a lead-time of five months can only be found over Sabah during January-February-March period. In another study, Juneng et al. (2010) showed that the forecast skills can be improved if dynamical and statistical approaches can be combined. In this study, a number of dynamical seasonal forecasts from several General Circulation Models (GCMs) were used as input to the CCA. This type of modelling is commonly referred

as a Model Output Statistics (MOS) approach and by averaging the results from several GCMs, multi-model ensemble method was actually used. Using this method,

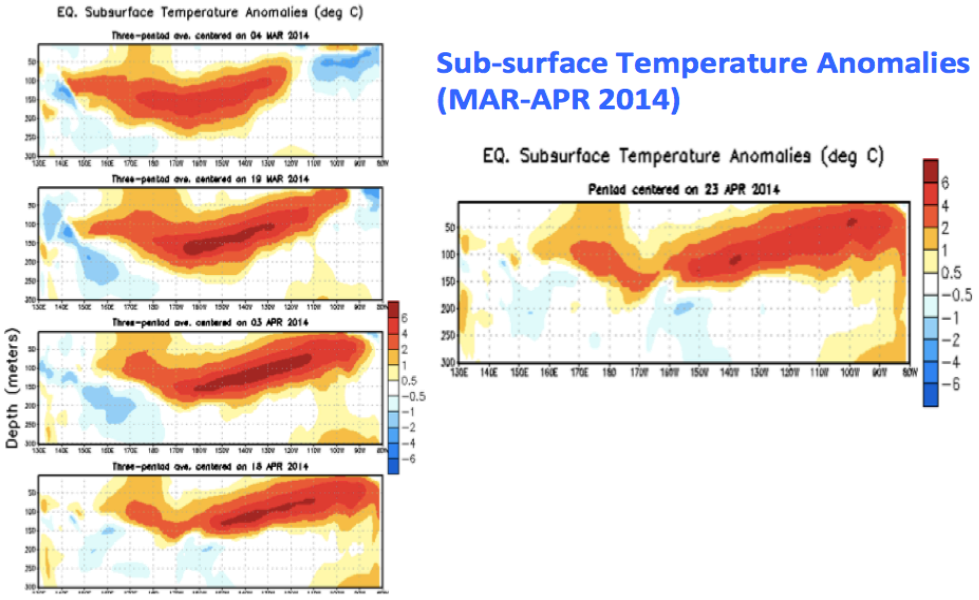


Figure 2.17 The evolution of subsurface temperature anomalies along the equatorial Pacific Ocean from early March 2014 to the third week of April 2014, indicating thermocline depressions by Kelvin waves. The plot was provided by the CPC NCEP NOAA

Juneng et al. (2010) showed skill improvements particularly over Peninsular Malaysia. In a recent work, Salimun et al. (2014b) also indicated GCM seasonal forecast usually had lower forecast skills in forecasting rainfall anomaly over Malaysia due to the low resolution of such global model and the complexity of regional circulation over the region. However, using a MOS approach, forecast skills can be improved.

2.7 Recent development in the tropical Pacific Ocean

During the early months of 2014, Peninsular Malaysia experienced severe drought due to strong and persistent MJO propagations from Indian to the Pacific Ocean. However, during the same period, interior parts of Sabah experienced floods. Droughts and floods were typical impacts of the suppressed and enhanced convective envelopes when they were propagating eastward associated with this phenomenon. Interestingly, MJO propagations also could trigger strong westerly over western Pacific Ocean. Figure 2.16 indicates the occurrences of strong westerly winds over the western Pacific Ocean from middle of January 2014 to early February 2014, from middle of February 2014 to early March 2014 and from early April to middle of April 2014.

As outlined in Section 2.2, such bursts of westerly wind provide the energy for the generation of packets of downwelling Kelvin waves that propagate eastward to east coast of the Pacific Ocean depressing the thermocline along their paths. The signatures of depressed thermocline are shown in Figure 2.17. Throughout the months

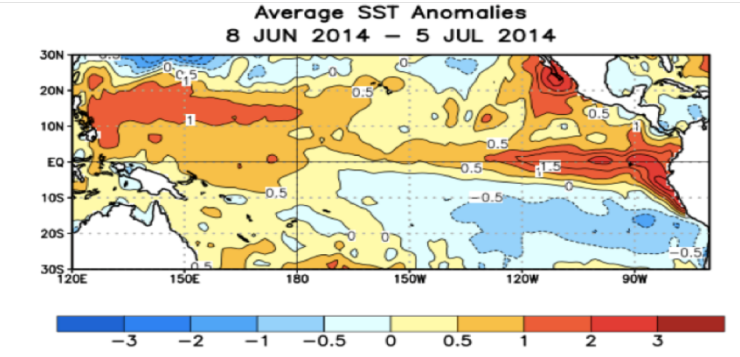


Figure 2.18 Average SST anomalies during a period from 8 June 2014 – 5 July 2014. Unit is °C. The plot was provided by the CPC NCEP NOAA

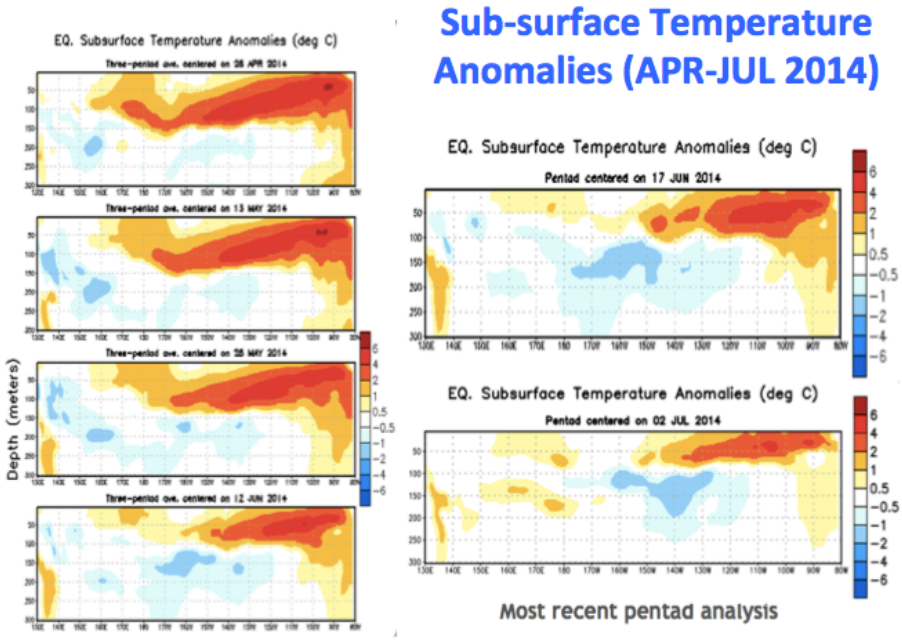


Figure 2.19 As in Figure 17 except for a period of 24 April 2014 – 02 July 2014. The plot was provided by the CPC NCEP NOAA

of March and April 2014, strong depressions of thermocline were indicated and these were due to the Kelvin waves generated in earlier months. These early developments were similar to those of the strongest 1997/98 El Niño, prompting many scientists to believe that another strong El Niño was underway. The spatial pattern of SST anomaly during 8 June – 6 July 2014 (Figure 2.18) clearly indicated an early stage of El Niño development. At Niño3 and Niño1+2 regions, temperature anomalies have already exceeded 1.5°C. In early 2014, the CPC of NOAA issued ENSO advisory with probability of more 50% for an El Niño to occur in the boreal summer of 2014.

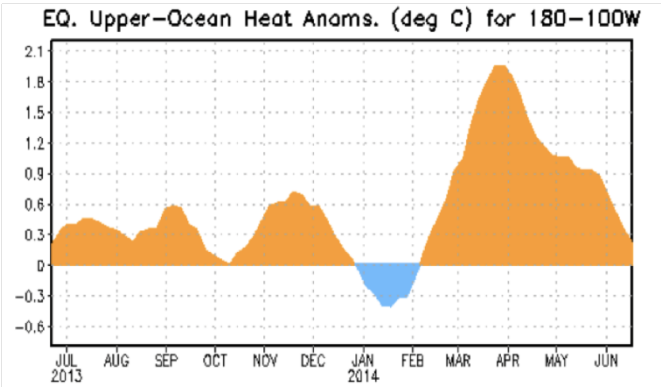


Figure 2.20 The equatorial upper-ocean heat anomalies for 180-100W from July 2013 to June 2014. Unit is °C. The plot was provided by the CPC NCEP NOAA

Despite the favourable conditions at the surface, developments at the subsurface appeared unfavourable for sustaining further development of the El Niño. By June and July 2014, the Kelvin waves activities significantly reduced (Figure 2.19). This could be due to the absence of westerly wind burst starting in mid-April until June 2014. This was also reflected in the equatorial upper-ocean heat anomalies where the values peaked in April 2014 but continued to decrease after that (Figure 2.20). Niño indices also showed declined and in fact, the Niño3.4 Index did not reach 0.5°C for the event to be officially declared as an El Niño event (Figure 2.21).

The failure of this event to develop after the "perfect kick-start" in April 2014 poses an interesting question to investigate. In fact, the initial warming at the eastern Pacific in June 2014 (Figure 2.18) should have trigged the weakening of easterly trade winds and weakened the east-west sea level pressure gradient that could trigger more packets of Kelvin Waves to sustain the development of the event. In fact, the International Research Institute for Climate and Society (IRI)/CPC in early June 2014, issued an ENSO forecast with more than 70% probability of occurrence during the boreal summer of 2014 (Figure 2.22). The questions of whether the "perfect kick-start" failed to initiate the subsequent ocean-atmosphere interactions or the ocean-atmosphere interaction failed to weaken the trade winds require further investigation. However, had the event evolved into a very strong El Niño similar to the 1997/98 event, Malaysia would have suffered tremendously given the fact it had already endured a drought period in March and April 2014 due to the MJO in which it itself considered to have initiated the development of the event.

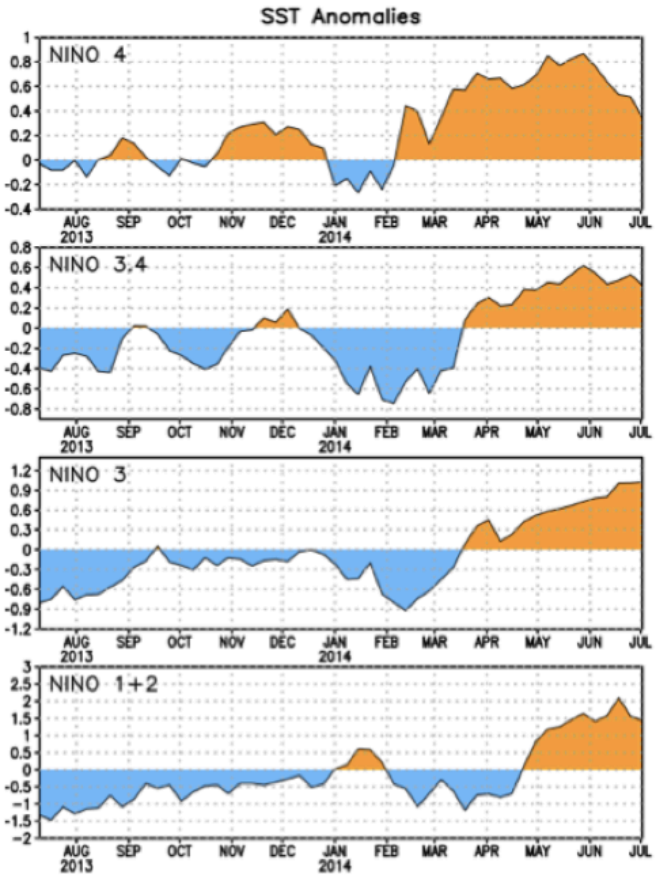


Figure 2.21 Time series of Niño indices from July 2013 until July 2014. Unit is in °C. The plot was provided by the CPC NCEP NOAA

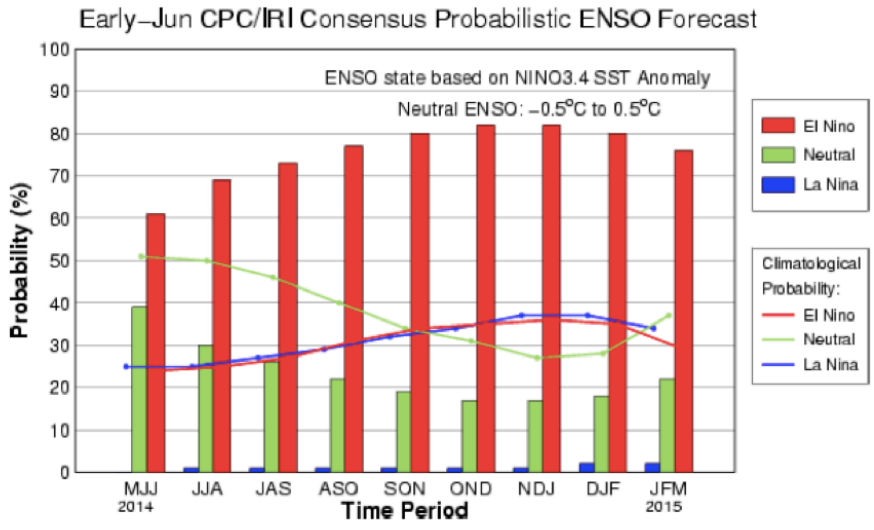


Figure 2.22 The IRI/CPC probabilistic ENSO forecast issued in early June 2014. The plot was provided by the CPC NCEP NOAA

Despite the "aborted" El Niño development in June 2014, the ocean-atmosphere interaction over the tropical Pacific Ocean re-strengthened during the spring of 2015 and subsequently the coupled system evolved into the 2015/2016 El Niño (Figure 2.23). Since April 2015, the SST anomaly in the tropical Pacific Ocean had gradually increased and by May

2015 the entire equatorial Pacific Ocean had warmed up above normal temperature indicating the ongoing development phase of the 2015/2016 El Niño. The surface warming continued for the next couple of months and peaked during November or December 2015 (Figure 2.24). By January 2016, the SST anomaly began to decrease indicating the decaying phase of the El Niño event. The 2015/2016 El Niño was forecasted to end by May or June 2015. According to the March 2016 forecast of CPC/IRI, there is about 50% likelihood that La Niña may develop by September or October 2016. Anomalously strong northeast monsoon later this year is expected if La Niña develops in September or October 2016.

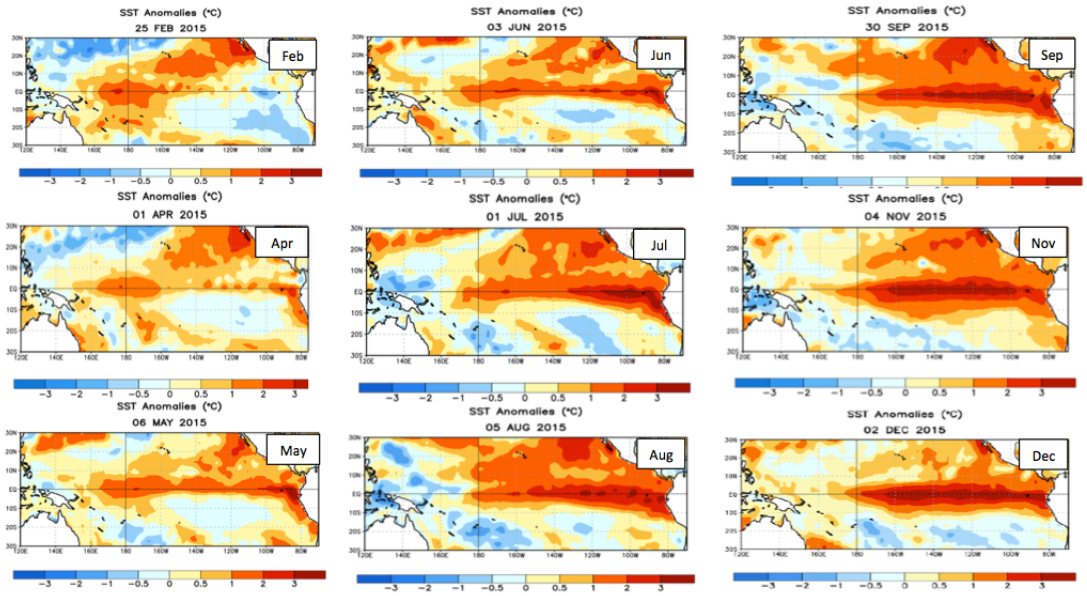


Figure 2.23 The SSTA depicting the evolution of the 2015/2016 El Niño. The plots were provided by the CPC NCEP, NOAA

Based on the magnitude of the SST anomaly increases, the intensity of the 2015/2016 El Niño is comparable to that of the 1997/98 El Niño. Both are considered as a conventional type of El Niño. The evolution of these two El Niño events is also remarkably similar. In terms of impacts, the severity of droughts was also similar. The Indonesian region of Sumatra and Kalimantan had experienced severe drought conditions from June to November 2015 and this provided favourable conditions for widespread forest fires in the region. The uncontrolled forest fires in Kalimantan and Sumatra had resulted into another severe haze episode that engulfed a number of countries in the Southeast Asia region including Malaysia for a continuous three months period from September to November 2015.

By January 2016, the El Niño-induced drought condition shifted to northern Sarawak and Sabah. In February 2016, a number of newspaper reports indicated drought condition enraged in areas such as Miri, Bekalalan Sarawak and Tawau Sabah. Forest fires and serious haze have also been reported in Miri. Interestingly, during the same time, areas in the southern part of Sarawak including Kuching, Kota Samarahan have experienced above normal rainfall and floods. Pontianak in Kalimantan had also experienced similar floods during the same period (as reported in Tribun Pontianak). The opposite conditions i.e. drought over northern Sawarak and Sabah and wetter-than-normal (possibly flood) in

southern Sarawak and Kalimantan are very much consistent the typical El Niño-induced effect in northern Borneo as indicated Figure 2.13. In fact, the Asia-Pacific Economic Cooperation (APEC) Climate Center (APCC) in Busan, South Korea, had also issued a probabilistic forecast in January 2016 that covered a period from February to April 2016 with 80% likelihood of drier-than-normal condition for northern Sarawak and Sabah while 80% likelihood of wetter-than-normal condition for southern Sarawak and Kalimatan (Figure 2.25). As forecasted, northern Sarawak and Sabah experienced severe drought condition from February to April 2016. Peninsular Malaysia, especially the northern region was also affected.

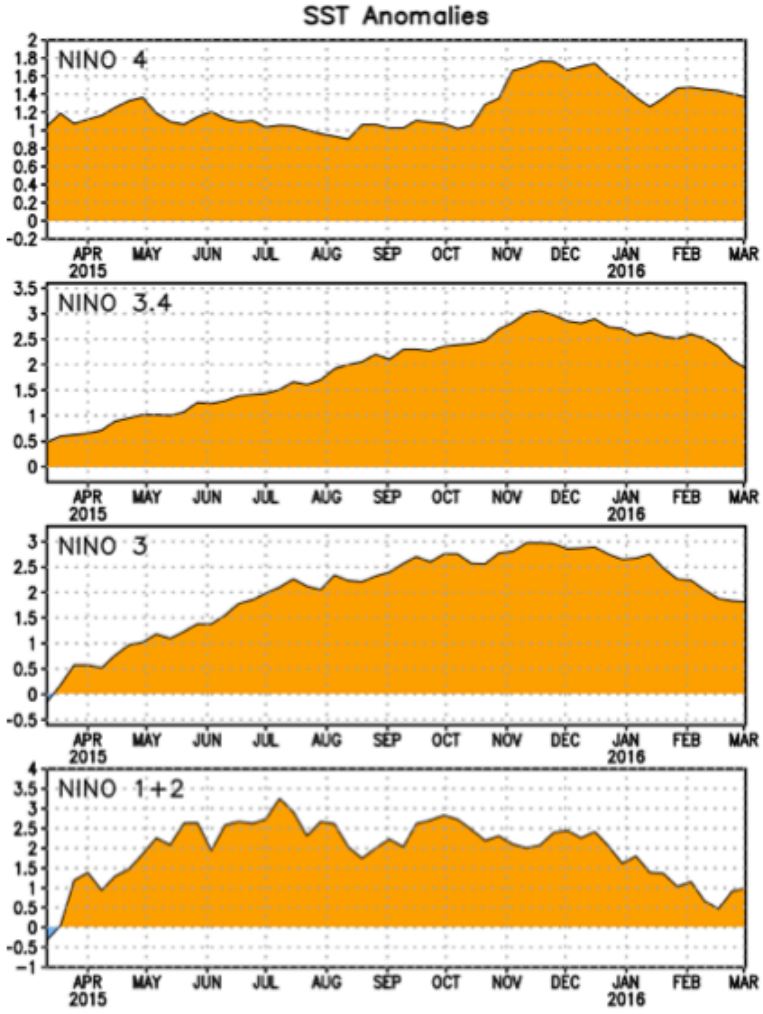


Figure 2.24 The Niño indices as in Figure 2. 21 except for duration from March 2015 to March 2016

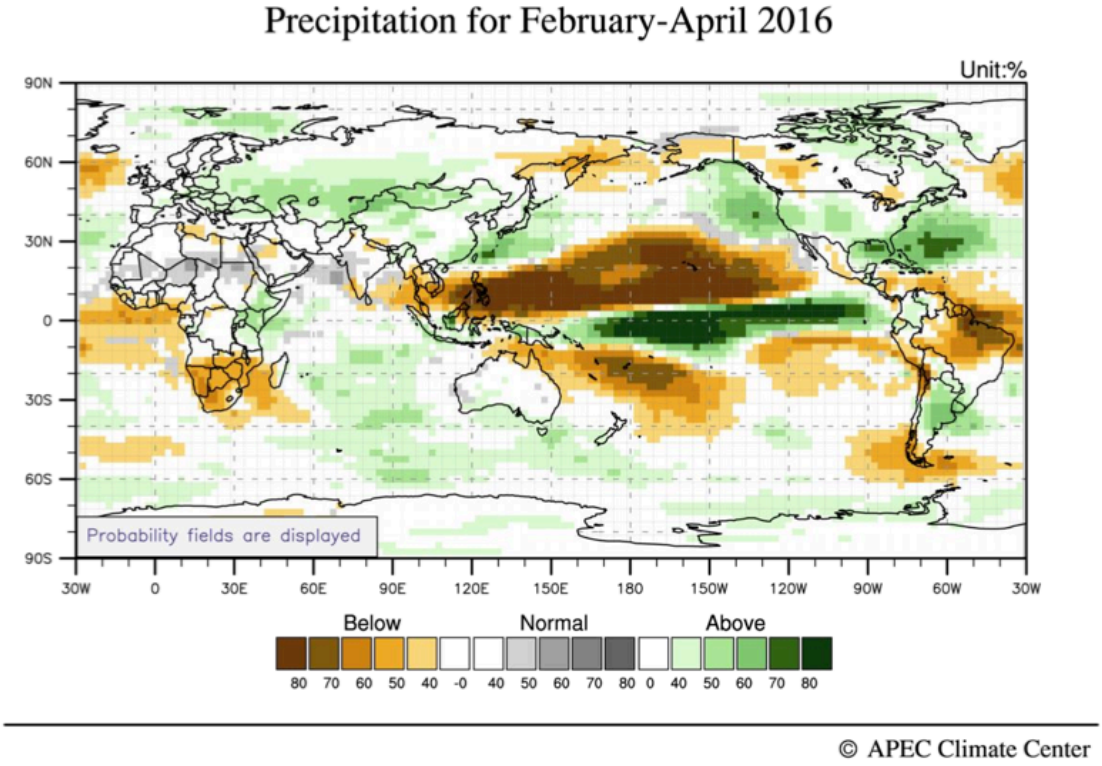


Figure 2.25 The APCC rainfall probabilistic forecast for February to April 2016 issued in January 2016

2.8 El Niño and climate change

The question of whether and how ENSO and its teleconnections would be changing in a warmer future climate is an important one. The IPCC Fifth Assessment Report (AR5) of Working Group 1 in its Chapter 14 (Climate Phenomena and their relevance to regional climate change) addresses this question. The finding of this report indicates that ENSO will remain the dominant mode of inter-annual variability in a warmer future climate. Also, due to the changes in moisture availability in a warmer future climate, ENSO-induced rainfall variability in regional scales will intensify (Christensen et al. 2013). The report also indicates that models without external forcing also show similar modulation as observed and hence there is little consensus of whether long-term ENSO changes can be attributed to external forcing or natural variability (Christensen et al. 2013). There is also low confidence that ENSO will intensify or change its spatial pattern (Christensen et al. 2013). However, a recent study by Cai et al. (2014) (not assessed by IPCC in AR5) indicated that the frequency of extreme El Niño such as the 1982/83 and 1997/98 episodes may increase in a warmer future climate.

2.9 Scientific gaps within the context of Malaysia

Significant progress has been made in scientific understanding of how ENSO modulates regional climate, particularly over Malaysia (Tangang et al., 2012). However, large knowledge gaps remain, particularly in terms of how the frequency of extreme El Niño and its teleconnection patterns over the South East Asian region will change in a warmer future climate. The latest IPCC AR5 seems inconclusive on whether ENSO will intensify. Nonetheless, Cai et al. (2014) indicated that the frequency of extreme El Niño is projected to increase in a warmer climate. These would have profound impacts not just in Malaysia but

also the Southeast Asia region. More research needs to be carried on this issue. More research also needs to be conducted on IOD and how it will affect Malaysia in a warmer future climate. Malaysia also needs to develop its seasonal climate forecasting system that could incorporate changes from the Indian Ocean and the Pacific Ocean.

2.10 Summary

The ENSO phenomenon is the largest inter-annual climate fluctuation in the Earth's climate system and it occurs naturally due to the coupled atmosphere-ocean interaction in the Pacific Ocean. Malaysia is impacted by this phenomenon but the severity of the impacts depends on the intensity. During an El Niño event, Malaysia tends to experience drought condition. However, this depends on season, location and also types of the El Niño. During a La Niña event, Malaysia tends to experience the opposite. For the last three decades, tremendous progress has been made in scientific understanding of ENSO system, both in theoretical and observational aspects. The setting up of the TAO Arrays in 1994 made the monitoring of the state of ENSO system possible in almost real time. Coupled with various forecasting systems, the development of ENSO can be predicted and tracked in almost real time. Malaysia needs to monitor this phenomenon using forecast products from established forecast centres. In addition, Malaysia also needs to increase its research on local and regional climate variability and build its own seasonal forecasting system.

Chapter 3: Environmental, Social and Economic Impacts of the 1997/98 El Niño event in Malaysia

3.1 Introduction

While the environmental, social and economic impacts of the strong 2015/16 El Niño event in Malaysia have yet to be assessed, this chapter draws lessons from the similarly strong 1997/98 El Niño event, with particular focus on the following sectors and areas:

- Water resources
- Energy
- Agriculture
- Forestry
- Industries
- Marine and terrestrial ecosystems
- Air quality
- Health
- Education and Tourism

The coverage of this chapter is constrained by the lack of data.

3.2 Water resources

Malaysia's water resources are mainly dependent on rainfall, which is influenced by the monsoon seasons. It has an annual average rainfall ranging from about 2,500mm in Peninsular Malaysia (notably wettest in August) to 5,080mm in East Malaysia (notably with main rainy season from November to February)[5]. . Most of Malaysia's agriculture, forests and biodiversity are rain-fed (MONRE, 2011).

The 1997/98 El Niño event caused extensive and prolonged drought in Malaysia, though the severity of affected areas varied.

Ahmad and Low (2003) highlighted the following:

- Between late January and mid-April 1998, most parts of Malaysia received less than one-fifth of the normal expected rainfall. As a result, there was water shortage, giving rise to a water crisis that afflicted many states, not only in Peninsular Malaysia (e.g., Selangor - including Kuala Lumpur Federal Territory; Penang, Kedah, Kelantan), but also in East Malaysia (Sabah and Sarawak). In particular in Bangi and Kajang, which draw water supply from the upper Langat River catchment, there were periods of domestic water supply disruptions during April-September 1998, which affected 1.8 million residents in the Klang Valley.

- In Sarawak, between July to September 1997, a prolonged dry spell was experienced in western part where a number of stations recorded more than 30 days without rain. Since the end of December 1997, the north-eastern region around Miri was seriously affected where the station recorded 102 days without rain - the longest period for no-rain ever recorded in the state. The dry spell had resulted in wildfires that had destroyed a sizable area of agriculture crops, and caused schools shut down due to poor air quality because of haze. The impacts related to haze are discussed in Section 3.9.

- Minimum river flows were observed in various rivers. For example, Langat River at Dengkil recorded a minimum flow of 0.94 m^3/s. The reduced water flow has also been contributed by uncontrolled development, such as the extensive urbanisation process on the catchment where natural vegetation has been replaced by paved surfaces, and

[5] https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-in-Malaysia

numerous storages or depressions (mining ponds) have been filled up and paved. This has resulted in less infiltration to the groundwater thus reducing the base flow rate. In addition, domestic and industrial discharges have also compounded the low flow characteristics.

- Sabah was most affected by the 1998 drought as it suffered extremely high rainfall deficit (some as low as 90% of long-term mean) from four to nine months. Water rationing was imposed in a number of districts, affecting more than 2,797 km^2 and 170,000 people. About 1580 km^2 was engulfed in wild fire, of which more than 100 km^2 were agricultural lands. More than 7,200 farmers were affected. The authority needed to send in food supply to the affected areas where the hill paddy crops were completely wiped out.

Mastura Mahmud (2009a) reported that at Kuching, Sarawak, the total average rainfall of 887mm from May to October in 1997 were 40% below the 30-year climatological mean total of 1,487mm.

A joint report (2014) prepared by the MMD, Department of Irrigation and Drainage (DID) and Forest Research Institute of Malaysia (FRIM) indicated that the 1998 drought affected Malaysia from Perlis to Negeri Sembilan and Melaka, and the worst hit region was the Federal Territory of Kuala Lumpur and part of Selangor where water rationing had to be exercised. Some 3.2 million users were affected for about five months (April to September) during the "national water crisis" in 1998.

The 1997/98 El Niño event exposed Malaysia's fragile water security situation that it is extremely susceptible to water stress, be it in excess or deficit (Chan, 2004).

Tawang and Tengku Ahmad (2003) compared the differences in the total amount of annual rainfall between normal and El Niño years. In particular, during the 1997/98 El Niño event, the total annual rainfall registered a deficit of 9% and 23% for Kedah and Perlis, respectively. The monthly deficits for the months of March to July 1997 were higher, with Kedah received only two-thirds of its normal rainfall, while Perlis received 73% of its normal rainfall. It may be noted that the significant rainfall deficits from January to May coincided with the off-season paddy planting.

As Kedah and Perlis are important agricultural and food producing areas in the country, any rainfall deficits would have profound impacts on rice productivity and food security.

The water deficit in various parts of Malaysia has a "knock-on" effect on other socio-economic sectors, as evidenced in the discussion in the following sections.

3.3 Agriculture

Agriculture is one of the key economic sectors in Malaysia. The sector contributed 9.2% to the Gross Domestic Product (GDP) in 2014 (Department of Statistics Malaysia, Official Portal)[6].
. It is highly vulnerable to the influences of El Niño events, both in terms of rainfall deficits and temperature changes. Tawang and Tengku Ahmad (2003) found that in Kedah and Perlis where they conducted their study, the mean monthly temperature, maximum and minimum temperatures were higher during the El Niño years compared to those of normal years. For example, the mean monthly increases in temperature during the 1997/98 El Niño event were 1.09 °C for Kedah and 1.6°C for Perlis.

[6] https://www.statistics.gov.my/index.php?r=column/ctwoByCat&parent_id=45&menu_id=Z0VTZGU1UHBUT1VJMFlpaXRRR0xpdz09

3.3.1 Responses of crops to drought and temperature

Mohamad Zabawi Abd. Ghani (2014) explained the effects of drought and high temperature on agricultural crops, which respond differently for different crops. Drought stress decreases the rate of photosynthesis of plants, hence hindering their growth and reducing their productivity. The effects of drought on crops depend on plant growth stage, stress intensity, water shortages and duration of the condition. Short-term crops with shallow roots such as vegetables, corn, paddy and peanuts are easily affected by drought even in a short period of time. It seems that drought affects the yield from flowering, fruiting and grain producing plants more than the yield from leafy plants, especially during flowering stage. As perennial crops such as fruit trees, cocoa, rubber and oil palm have deep root system that enables them to get water supply from soil for normal growth, the impact of water shortage for a short time period during drought is not significant. However, prolonged period of drought will limit their growth and production of the fruits. For example, in the case of star fruit, it was observed that a two-month drought could stunt the plant's growth, resulting in reduced flower production and smaller fruits. Drought condition also affects papaya growth, including flowers drop off, structural change in fruit, as well as causing an infertility phase. Cocoa plant, a perennial crop, is also sensitive to water shortage. However, for mild stress of water shortage, the plant produces more fruits instead.

Reaction of perennial crops to high temperature varies. Mohamad Zabawi Abd. Ghani (2014) noted that most tropical plants have minimum, optimum and maximum temperature for growth. If temperature increases beyond critical level for a long period of time, plant experiences photorespiration, where most of the biomass/food produced through photosynthesis is reused for respiration, resulting in less biomass/yield harvested. For paddy, the impact of high temperature varies according to various growing stages. If high temperature condition occurs after grain filling stage, it tends to accelerate maturity and harvesting period. On the other hand, if it occurs at seedling production stage, it is very likely that the seedlings will decrease, followed by reduction in yield.

3.3.2 Impacts of the 1997/98 El Niño on agricultural crops

Table 3.1 shows the yield of three major commodities of Malaysia, oil palm, rubber and paddy from 1992 to 2003. The data are also plotted in Figure 3.1.

Table 3.1 Oil palm, rubber and paddy yield in Malaysia from 1990 to 2003

Yield (kg/ha)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Oil palm	18,530	17,850	17,830	20,260	18,420	18,930	18,950	19,100	15,980	19,260	18,330	19,140	17,970	18,990
Rubber	1,329	1,338	1,332	1,293	1,417	1,291	1,301	1,273	1,330	1,447	1,289	1,358	1,381	1,343
Paddy	2,769	2,818	2,992	3,035	3,061	3,162	3,251	3,068	2,883	2,941	3,064	3,110	3,238	3,360

Source: Data from Department of Statistics Malaysia，Official Portal
https://www.statistics.gov.my/index.php?r=column/ctimeseries&menu_id=NHJlaGc2Rlg4ZXlGTjh1SU1kaWY5UT09

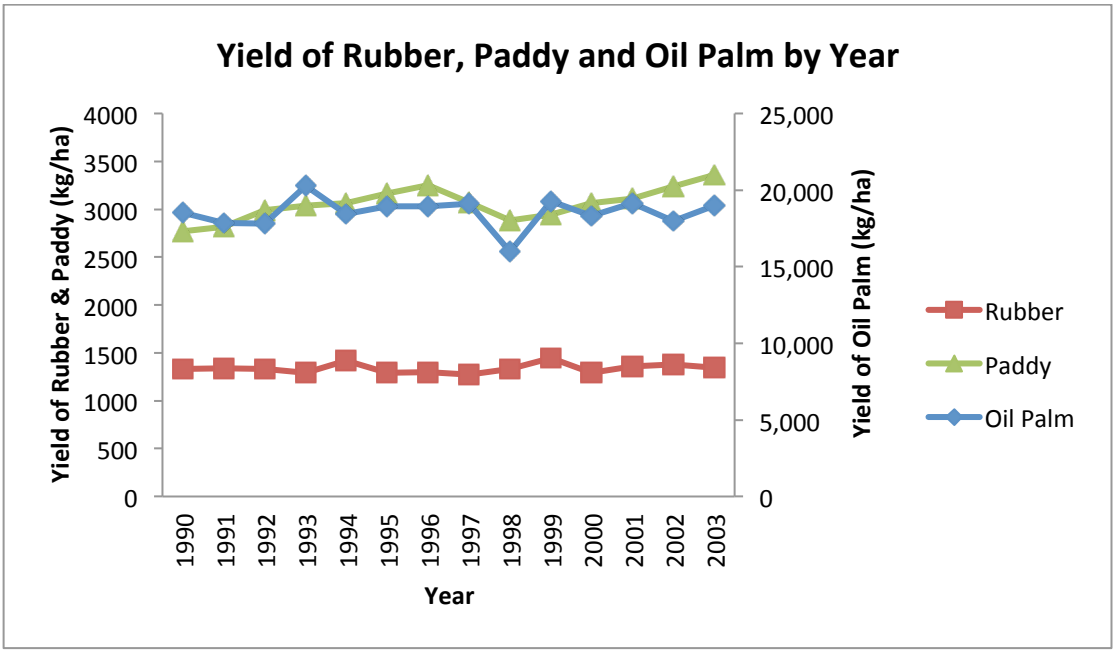


Figure 3.1 Oil palm, rubber and paddy production in Malaysia from 1990 to 2003

(A) Oil palm production

Oil palm production, and hence the price movement, are greatly affected by rainfall. A continuous low rainfall (←100 mm) for two months would have significant effects on palm yield, as evidenced in the past severe El Niño events (Haniff et al., 2010).

The 1997/98 El Niño event significantly affected the oil palm yield and productivity in Malaysia. As shown in Table 3.1 and Figure 3.1, the "Yield per Hectare" of oil palm in 1998 showed a significant decrease compared to previous years and the years after, from 18,950kg/ha in 1996, 19,100kg/ha in 1997, decreased to 15,890kg/ha in 1998 (or a drop of 16.8% from 1997 to 1998), and then increased to 19,260kg/ha in 1999. Ironically, the oil palm price was the highest since 1960, at RM2377.50 RM/tonne (Department of Statistics, Malaysia, Official Portal).

Bank Negara Malaysia (1998) reported that "Crude palm oil production recorded a decline of 8.3% to 8.3 million tonnes in 1998. The decline was due mainly to lower yields brought about by the reversal in the biological yield cycle of the oil palm trees, which occurs once every three or four years. To some extent, the lower yields were also attributable to the lagged impact of the haze and dry weather, which occurred during the second half of 1997, while labour shortages resulted in a
lower harvest as loose fruits tended to be uncollected."

Similar significant decrease was also observed in 1983, another strong El-Niño year, from 17,750kg/ha in 1981, 20,140kg/ha in 1982, decreased to 15,900kg/ha in 1983 (or a drop of 21.1% from 1982 to 1983), and then increased to 18,190kg/ha in 1984 (Table 3.2, and Figure 3.2).

Table 3.2 Oil palm, rubber and paddy yield in Malaysia from 1981 to 1986

Yield (kg/ha)	1981	1982	1983	1984	1985	1986
Oil palm	17,750	20,140	15,900	18,190	18,950	18,980
Rubber	1,425	1420	1,419	1,387	1,414	1,492
Paddy	2,842	2,762	2,605	2,491	2,975	2,640

Source: Data from Department of Statistics Malaysia，Official Portal, https://www.statistics.gov.my/index.php?r=column/ctimeseries&menu_id=NHJlaGc2Rlg4ZXlGTjh1SU1kaWY5UT09

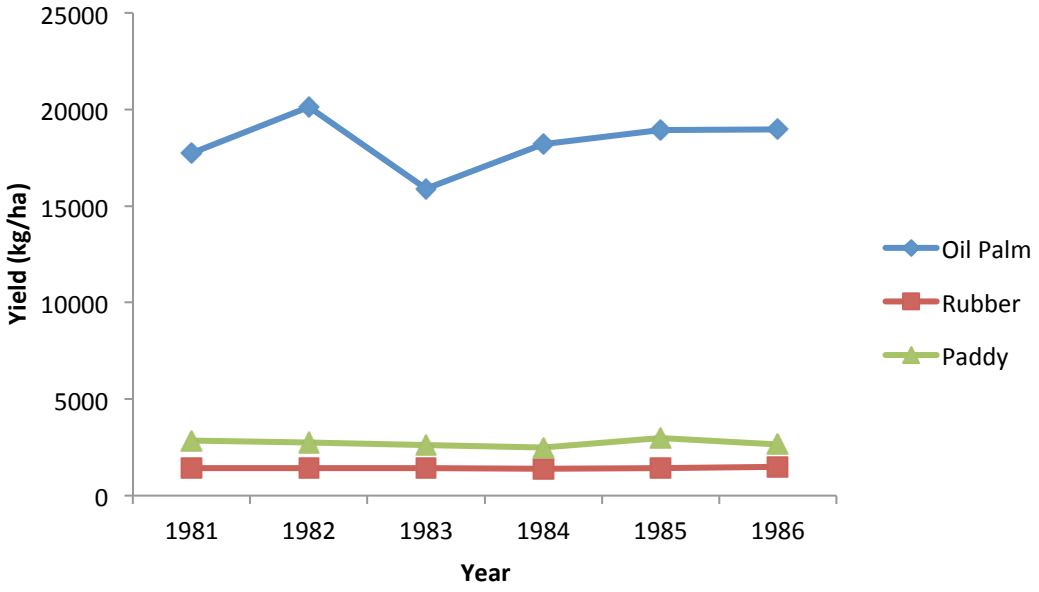


Figure 3.2 Oil palm, rubber and paddy production in Malaysia from 1981 to 1986

The oil palm price was RM991.00 RM/tonne in 1983, slightly higher than the price in 1981 but lower than the price in 1984. This shows that the market price of oil palm is determined by many factors (Department of Statistics Malaysia, Official Portal: Oil Palm).

Haniff et al. (2010) analysed rainfall and oil palm yield records from 1995 to 2009, and showed that severe El Niño occurrence often resulted in months with less than 100mm of rainfall at the beginning of each month in the year. In 1998, the number of months with less than 100mm of rainfall was one month for Sarawak, three months for Peninsular Malaysia and four months for Sabah. It seems that the number of months receiving less than 100mm of rainfall could be coupled to the reduction in fresh fruit bunches (FFB) yield. Haniff et al. (2010), however, found the mechanisms difficult to explain since they could be a combination of complex long-term and short-term stress responses by the palms.

Tawang et al. (2002) found that oil palm yields decreased when the Total Suspended Particulates (TSP), an indicator of air quality, increased. During El Niño events, the concentrations of TSP were high because of the occurrence of haze, which affected the photosynthesis of plants due to reduced sunlight. Even without the occurrence of haze, a drier weather condition during an El Niño event is expected to be more inductive to higher levels of TSP.

Shahwahid and Othman (1999) observed that the 1997/98 haze episode had a delayed effect on oil palm crops. When the haze event occurred, fruit bunches were already grown,

some matured, while others still young. Therefore, a decline in the FFB production was not obvious between September and early December 1997, other than the normal decline that begins once the high-yield season of August and September was over. The low yield in January and February 1998 was due to low fertilization rates in September 1997. However, in an extended study, Haniff et al (2016) found that annual FFB yield in 1998 was significantly reduced compared to that in previous years, and they attributed the yield reduction to the severe 1997/98 El Niño event. The economic impact of the haze impact in 1997/98 on oil palm is still unclear, though yield reduction brings higher FFB prices (Shahwahid and Othman, 1999).

(B) Rubber yield

At least during the short-term, the rubber yield did not seem to be affected by the El Niño event in 1997/98, with 1,301kg/ha in 1996, 1273kg/ha in 1997 and 1330kg/ha in 1998, and an increase to 1,477kg/ha in 1999 (Table 3.1 and Figure 3.1).

However, during 1982/83, another strong El Niño event, the rubber yield in 1981, 1982 and 1983 were about the same (i.e., 1,425, 1,420, 1,419kg/ha, respectively), though there was a slight decrease from 1,419kg/ha in 1983 to 1,387kg/ha in 1984 (or a drop of about 2.3% from 1983 to 1984), which may not be statistically significant (Table 3.2, and Figure 3.2) (Department of Statistics Malaysia, Official Portal: Rubber).

It has been reported that on the rubber estate, El Niño contributed positively due to the increase in the number of tapping days, which resulted in an increase in yield and income. Other benefits included the reduction in the application of weedicides and fertilizers (Tawang and Tengku Ahmad, 2003).

(C) Paddy yield

The 1997/98 El Niño event clearly affected the paddy yield. As shown in Table 3.1 and Figure 3.1, the paddy yield dropped from 3,251 kg/ha in 1996, to 3,068 kg/ha 1997 and to 2,883kg/ha in 1998 (or about 11.3% from 1996 to 1998), before a slight increase to 2,941kg/ha in 1999.

Similar effect was also evident during another strong El Niño event in 1982/83, when the paddy yield dropped from 2,842kg/ha in 1981 to 2,762kg/ha in 1982, to 2,605kg/ha in 1983, and to 2,491kg/ha in 1984 (or about 12.4% from 1981 to 1984, before a slight increase to 2,975kg/ha in 1985 (Table 3.2 and Figure 3.2) (Department of Statistics Malaysia, Official Portal: Paddy).

Figure 3.3 shows the paddy and rice production from 1992 to 2003, which correlated well with each other.

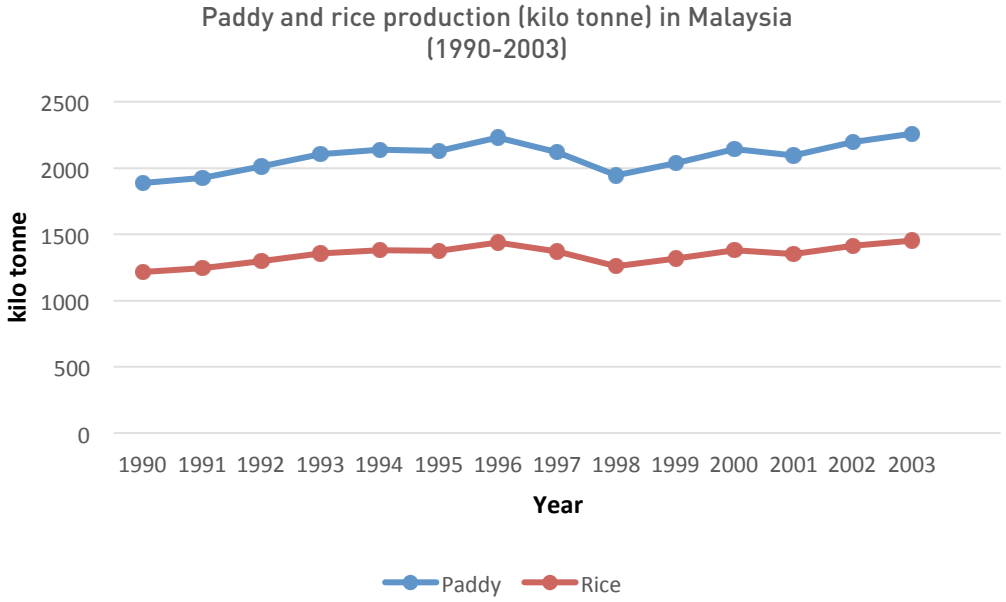


Figure 3.3 Paddy and rice production from 1990 to 2003

Tawang and Tengku Ahmad (2003) found that rainfall and air quality were important factors that affected the paddy yield. The 1997 haze affected the level of sunlight, which was important for photosynthesis, and thereby reducing second harvest paddy yields, probably by about 10%, according to Shahwahid and Othman (1999). Indeed, the paddy yield dropped by about 11.3% from 1996 to 1998, as shown in Table 3.1 and Figure 3.3.

There are few details on how the reduced paddy and rice production due to the 1997/98 El Niño event affected the farmers' income. However, it has been reported that the shortfall of rice yields "necessitated the import of over million tons to safeguard food availability in Malaysia" (Abul Quasem Al-Amin and Gazi Mahabubul Alam, 2016).

(D) Cocoa

As shown in Table 3.3, the production of dry cocoa beans in Malaysia has been declining, from 121,185 tonnes in 1992 to 6,851 tonnes in 2003. One major factor is the conversion of cocoa plantations to other profitable ventures, especially oil palm (Bank Negara Malaysia, 1997).

Although the yield per hectare shows a small increase from 1996 (0.76 tonne/ha) to 1997 (0.81 tonne/ha) and 1998 (0.86 tonne/ha), the production of dry cocoa beans actually decreased from 54,778 tonnes in 1996 to 37,245 tonnes in 1997 and 29,972 tonnes in 1998, as shown in Figure 3.4. The above data make the assessment of the impacts of the 1997/98 98 El Niño event on the yield of cocoa difficult.

However, according to Bank Negera Malaysia (1997; 1998), the "severe drought arising from the El Nino weather phenomenon" had affected fruit setting particularly towards the second half of 1997, and "had also delayed the fruit setting for the second season" in 1998. "Besides the weather factor, cocoa output was also affected by rising production cost due to increased labour cost and higher prices of agricultural inputs." (Bank Negara Malaysia, 1998)

Table 3.3 Cocoa production in Malaysia from 1990 to 2003

Year	Production of dry cocoa beans (tonne)	Yield per hectare (tonne)	Total number of employment	Reduction in number of employment compared to previous year
1990	120,826	0.77	56,424	
1991	110,377	0.72	52,674	3,750
1992	121,185	0.85	46,733	5,941
1993	101,599	0.79	42,268	4,465
1994	78,932	0.69	37,393	4,875
1995	67,349	0.83	28,267	9,126
1996	54,778	0.76	23,848	4,419
1997	37,245	0.81	15,930	7,918
1998	29,972	0.86	12,472	3,458
1999	22,573	0.86	10,300	2,172
2000	16,941	0.82	7,765	2,535
2001	15,999	0.92	6,686	1,079
2002	10,203	0.73	5,640	1,046
2003	6,851	0.53	5,306	334

Source: Malaysian Cocoa Board (Data reported in Department of Statistics Malaysia, Official Portal)
https://www.statistics.gov.my/index.php?r=column/ctimeseries&menu_id=NHJlaGc2Rlg4ZXlGTjh1SU1kaWY5UT09

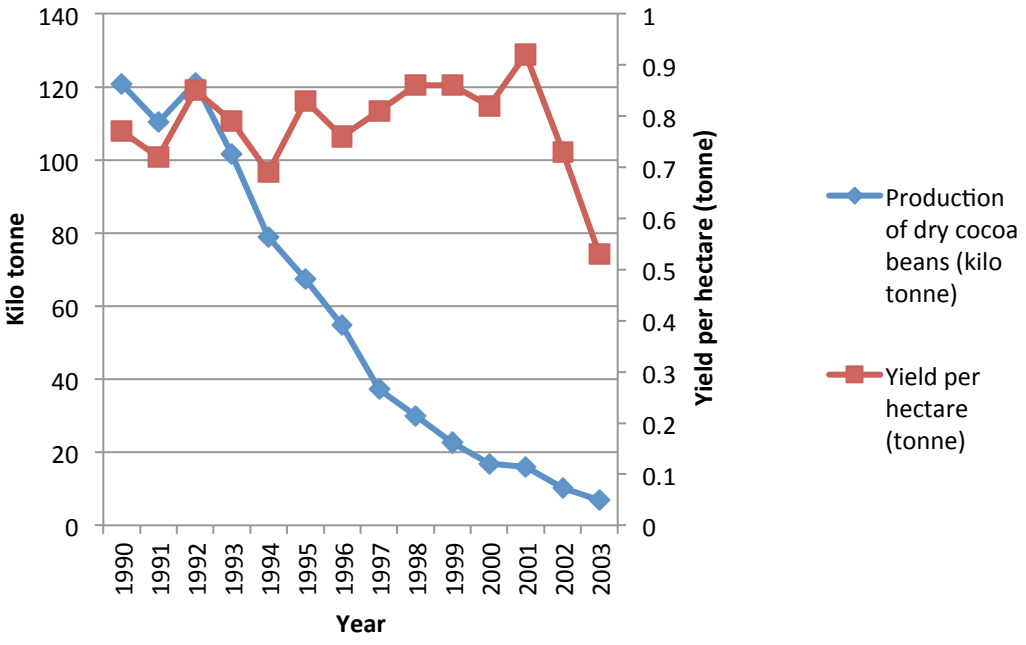


Figure 3.4 The production of dry cocoa beans from 1990 to 2003

It is noted that the total number of employment in the cocoa sector decreased from 1990 to 2003 (Table 3.3). In particular, there was a drastic reduction of employment from 23,848 in 1996 to 15,930 in 1997 (or a total of 7,918) compared to other previous years, with the exception of 1995.

3.3.3 Social and economic impacts on agricultural sector

Tawang et al. (2002) estimated the total economic loss of oil palm, rubber and rice from 1980 to 1999 due to the effects and impacts of El Niño events and it was more than RM3.3 billion, excluding the various secondary spin-off losses resulting from other

downstream activities. Of these losses, oil palm production accounted for RM2.651 billion[7] (or about 80.3%), followed by rubber, RM357 million[8] (or about 10.8%) and rice, RM218 million[9] (or about 0.6%). These losses had resulted in the loss of foreign exchange because of the loss from potential export earnings of palm oil (estimated at RM2,129 million in 1998) and rubber (estimated at RM179 million), as well as the need to import more rice to meet the country's demand (Tawang et al., 2002). However, Tawang et al. (2002) did not find evidence of significant productivity losses for other agricultural subsectors, such as fruits, vegetables, sugarcane, and selected livestock industries.

For the 1997/98 El Niño event, Tawang et al. (2002) estimated the economic losses of oil palm and paddy at RM1,982.0 million and RM159.6 million respectively for the year 1998. No estimate of economic loss for rubber was provided for 1998.

Based on the same methodology of Tawang et al. (2002), Tawang and Tengku Ahmad (2003) focused on the states of Kedah and Perlis in the northwest region of Peninsular Malaysia, and estimated the economic losses of oil palm for the Kedah-Perlis region at RM113.2 million due to the 1997/98 El Niño event[10]. They also estimated the economic losses of paddy for the Kedah-Perlis region at RM49.0 million[11] due to the 1997/98 El Niño event. However, they showed that the 1997/98 El Niño event did not seem to have significantly affected the yield performance of rubber in the same region.

3.3.4 Practical measures to reduce impacts on agricultural sector

Although limited mitigating measures have been introduced, a more holistic approach and comprehensive measures are needed to reduce the impacts of future El Niño events in the agricultural sector. As discussed by Tawang et al. (2002) and Tawang and Tengku Ahmad (2003), these include approach such as sustainable water resources management, including practices related to water management within the irrigation scheme; continuous improvement of irrigation infrastructures, and the enhancement of support services with improvements in storage, delivery and the distribution system so as to ensure an effective and efficient use of irrigated water; ability to reschedule water supply; application of an efficient water control and management system; water recycling; water saving agronomic practices and overall efficiency in water use. The most successful mitigating measure undertaken by the plantation in coping with drought was the construction of artificial lakes as a source of water supply. By using a mobile sprinkler system the effects of the prolonged drought period were drastically reduced.

3.4 Forestry

There have been some studies on the impacts of drought on forests. For example, Nakagawa et al. (2000) assessed the impacts of severe drought associated with the 1997/98 El Niño event in tropical forest in Sarawak. They compared that the tree mortality during non-drought period (1993-1997) and drought period (1997-1998), and found that the mortality rates during drought period were significantly higher than for the non-drought period. They concluded that the severe drought associated with the 1997/98 El Niño event had a big impact on tropical forest dynamic by causing unusually high mortality.

Aiba and Kitayama (2002) examined the effects of the 1997/98 El Niño drought on nine rain forests of Mount Kinabalu at four altitudes (700m, 1700m, 2700m and 3100m) on contrasting geological substrata (ultrabasic versus non-ultrabasic). Measurements of rainfall and atmospheric aridity indicated that the departure from normal conditions during the drought became greater with increasing altitude. During 1997–99 (drought period)

[7] For the years 1982, 1983, 1991 and 1998. See Table 5.5 of Tawang et al. (2002).
[8] For the years 1981, 1982 and 1990. See Table 5.8 of Tawang et al. (2002).
[9] For the years 1980, 1981 and 1998. See Table 5.11 of Tawang et al. (2002).
[10] Tawang and Tengku Ahmad assumed that for the case of oil palm, the effects of El Niño only impacted yield one year after of the event.
[11] For the years 1997 and 1998. See Table 4.11 of Tawang and Tengku Ahmad (2003).

compared to 1995–97 (pre-drought period), median growth rates of stem diameter of trees decreased for both smaller (4.8cm – 10 cm) and larger (↗ 10cm) diameter classes in the six upland forests (↗ 2700m on ultrabasic substrata and ↗ 1700m on non-ultrabasic substrata), but for neither diameter class in the other forests. The majority of species decreased or did not change growth rates during 1997–99, whereas some did increase. Tree mortality increased during 1997–99, at the larger diameter class in the two lowland forests (700m) on both substrata, and at least at the smaller diameter class in the four upland forests (↗ 1700m) on non-ultrabasic substrata. In two of these upland forests, mortality was restricted to particular understorey species. Mortality did not significantly increase in the three upland forests (↗ 1700m) on ultrabasic substrata; this suggests that the adaptation to nutrient-poor soils might have provided the resistance to drought.

Potts (2003) assessed the mortality rates of forests in the Lambir Hills National Park located in Sarawak for the pre-drought (1993–97) and drought periods (between late January and mid-April in 1998 when less than one-fifth of the normal expected rainfall was received). He found that the forest wide mortality rates during the drought were 7.63% per year as compared to 2.40% per year during the pre-drought period. In other words, the mortality rate during the drought period was three times higher than during the pre-drought period. Potts (2003) used logistic regression to investigate the habitat effects, and found that during the pre-drought period, soil type was the most important predictor of tree survival, while during the drought period, slope was the most important.

In addition, Potts (2003) found that during the drought, different families responded differently in terms of relative increases in mortality. Thus, drought may have induced changes in community diversity and composition. Nakagawa et al. (2000) also found that sensitivity and tolerance to drought varied among taxonomic groups. For the purpose of effective forest management during drought periods in Malaysia, it is important to assess the various disturbances or impacts imposed by drought on the survival between rare and common species, and establish the ecological basis of any differences (Potts, 2003).

Bank Negara Malaysia (1997) reported that heavy and thick haze during August and September in 1997 led to lower production of saw logs in the second half of the year, as harvesting operations were halted due to poor visibility.

3.5 Energy

Hydropower is the most vulnerable to prolonged drought. There was a significant decrease in electricity generated by hydropower stations during the 1997/98 El Niño event, from 5,139 million kWh (kilowatt-hour) in 1996 to 3,917 million kWh in 1997 (or a decrease of 23.8% from 1996 to 1997) and 4,799 million kWh in 1998 (or a decrease of 6.62% from 1996 to 1998) to 7,460 million kWh in 1999 (Department of Statistics Malaysia, Official Portal). The shortfall of hydroelectric was made up by the diesel and gas-generated electricity (Figure 3.5). This implies a higher cost for producing energy and a higher emission of greenhouse gases.

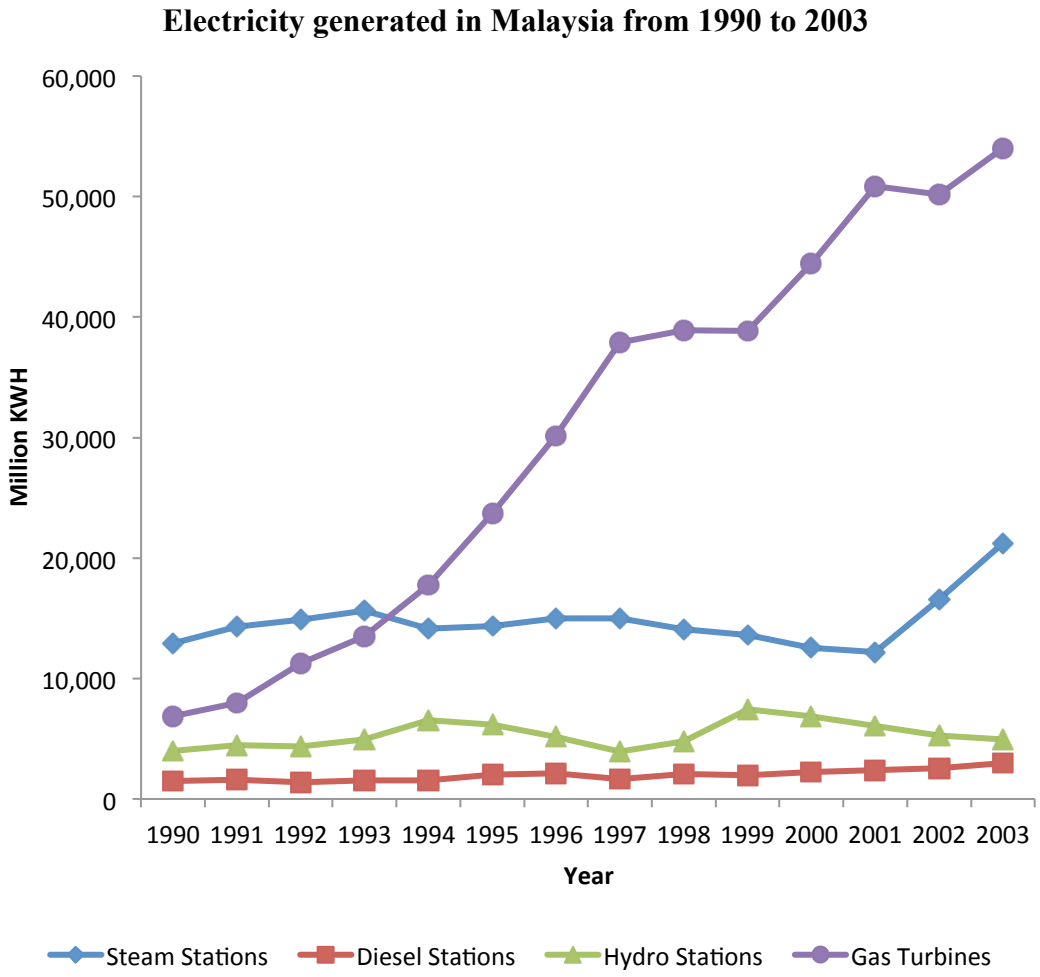


Figure 3.5 Electricity generated in Malaysia from 1990 to 2003

3.6 Industry

It is difficult to gauge the impacts of the 1997/98 El Niño event on industry without further analysis in each industrial subsector. It is expected that the subsectors that rely heavily on water resources would be more affected.

The GDP contributed by manufacturing decreased from RM53,387 million in 1996 to RM50,899 million in 1998 (or a decrease of 4.7%), and it recovered to RM56,840 million in 1999 (Department of Statistics Malaysia, Official Portal). The decrease in GDP contributed by manufacturing in 1998 could be due to the economic downturn exacerbated by the prolonged drought that affected the industrial production activities due to the constraint in water resources.

The industrial productivity index is plotted for mining, manufacturing and electricity, which clearly indicates a decrease in manufacturing from 1997 to 1998 (Figure 3.6).

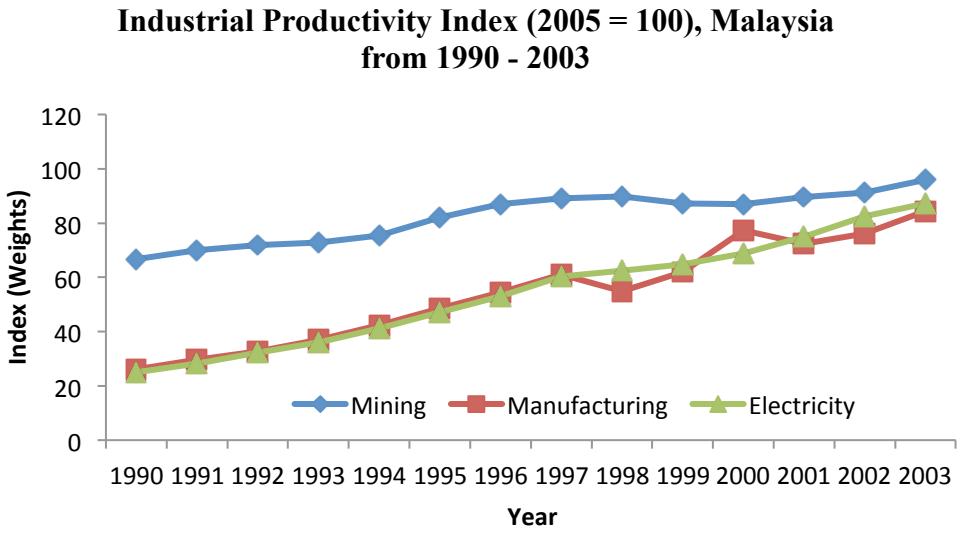


Figure 3.6 Industrial productivity index, Malaysia from 1992 to 2003

Source: Department of Statistic Malaysia: Official Portal

3.7 Ecosystems and ecosystem services

3.7.1 Terrestrial ecosystems

Ecosystems represent a key asset in Malaysia contributing to the national economy by providing food, water, as well as natural resources such as timber and fisheries that are major sources of national income.

However, very little is known about the impacts of the 1997/98 El Niño event on the terrestrial ecosystems, apart from the reported loss of endangered species and biodiversity due to drought-induced forest fires, which have profound effects on the structure and dynamics of the affected ecosystems (Schweithelm et al., 1999; Glover and Jessup, 1999).

The costs of many of the impacts of the forest fires and the associated hazes on the fragile terrestrial ecosystems as well as the loss of ecosystem services during the 1997/98 El Niño event are difficult to quantify due to the lack of data and research. Some of these effects could be long term, and it could take many years to recover (Hughes et al., 1998).

3.7.2 Marine ecosystems

In Malaysia, the coastal zone has a special socio-economic and environmental significance because many people rely on coastal ecosystems, such as coral reefs and mangroves, to provide their daily food and income (Sulaiman and Zainal Abidin, 2012).

(A) Coral reefs

Coral reefs provide important marine ecosystem services. They buffer adjacent shorelines from wave action and prevent erosion, property damage and loss of life (NOAA, 2008). They support important subsistence fisheries (WCMC, 1992), and contribute to local economies through tourism (NOAA, 2008).

Malaysia is part of the "Coral Triangle" (Figure 3.7), an area recognised by scientists to have the world's highest marine biodiversity. The total reef area in Malaysia is 4,000km^2, of which Sabah accounts for three-quarters. Coral diversity is highest in East Malaysia at an estimate of over 550 species while Peninsular Malaysia has over 360 species of coral.



Figure 3.7 The Coral Triangle
Source: NOAA, undated

Peñaflor et al. (2009) reviewed the sea-surface temperature and thermal stress in the Coral Triangle over the past two decades. Citing various literature (e.g., Wilkinson, 1998; McPhaden et. al., 2006; Oliver et al., 2009), they found that the Coral Triangle as a whole has experienced a pronounced increase in SST during El Niño events, including the intense ocean warming during the1997/98 El Niño event that led to the widespread occurrences of coral bleaching. It was estimated that the1997/98 El Niño event alone had caused the bleaching of 16% of the world's coral reefs (World Bank, 2007).

However, large proportions of the Coral Triangle in Malaysia have already been severely impacted by overfishing. By comparison, the main coral reef areas surrounding Sabah is in much poorer health than the rest of the country (WWF and UQ, 2009). Although the natural El Niño events continue to threaten the Coral Triangle, human caused factors, including human-induced global warming, continue to play a significant role in its degradation.

Although coral reefs bleaching have been widely reported during the 1997/98 El Niño event, there is a need for systematic scientific research on the impacts of El Niño events in the Malaysian coastal regions, including coral reefs. One particular interesting aspect is research on coral farming which may be undertaken to restore the dying and damaged reefs[12]

[12] http://www.coralvita.co/coral-farming/

(B) Mangroves

Mangroves also provide important ecosystems services, and its values are well documented in the literature. They are a significant source of wood and fuel, and they provide habitat for shellfish, crustaceans and fish (WCMC, 1992; MEA, 2005a; FAO, 2007; 2010). They are used by coastal communities as nurseries for many fishery species, and also as sites for agricultural production, especially rice production (MEA, 2005a).

The data provided by the Forestry Department Peninsular Malaysia (2017) show that the mangroves area in Peninsular Malaysia for the year 2014 was 110,000ha , while the total area of mangrove forests in Sabah was about 340,000ha in 2015 (Sabah Forestry Department, 2015), and 86,258ha in 2013 in Sarawak (Forestry Department Sarawak, 2013). The total area was about 536,258ha.

It was reported in 1992 that Malaysia had 630,000ha of mangrove forests of which 105,000ha were located in Peninsular Malaysia, 350,000ha were located in Sabah and 175,000ha were located in Sarawak (WCMC, 1992). It is clear that the total area of mangrove forests has been decreasing since the 1990s. Apart from Peninsular Malaysia that shows a slight increase in mangroves area (from 105,000ha in 1992 to 110,000ha in 2014), both Sabah and Sarawak have recorded a decrease, especially in Sarawak, which had about half of its mangrove area (86,258ha) in 2013 compared to 175,000ha in 1992.

The main drivers for these losses are attributed to illegal cutting, conversion to other uses (such as mariculture and other forms of coastal development) and land-based industrial pollution. Malaysia has a long tradition of production of mangrove charcoal for national and international markets (FAO, 2007). However， there have been efforts to restore the degraded mangrove areas (Forestry Department Sarawak, 2013; Sabah Forestry Department, 2015). For example, Sabah Forestry Department has planted a total of 1,220.21ha in degraded mangroves and coastal areas with suitable mangrove and associated species as of December 2015 (Sabah Forestry Department, 2015).

Gilman et al. (2008), citing Field (1995) and Ellison (2000), have highlighted the following expected impacts of increased surface temperature on mangroves:

- Changing species composition (extinction)
- Changing phenological patterns (e.g., timing of flowering and fruiting)
- Increasing mangrove productivity where temperature does not exceed an upper threshold
- Expanding mangrove ranges to higher latitudes where range is limited by temperature, but is not limited by other factors, including a supply of propagules and suitable physiographic conditions

However, the above expected impacts on mangroves are supposed to be in response to longer term climate change rather than the short-term El Niño events, even though El Niño events are likely to exacerbate the effects of climate change and vice versa. Interestingly, Holmgren et al. (2001) reported that El Niño effects have been linked to the almost complete defoliation of mangroves.

In view of the projected increase of El Niño frequency with global warming, the profound El Niño impact on ecosystems justifies a substantial future research effort to provide a comprehensive understanding of El Niño effects on terrestrial and marine ecosystems (Holmgren et al., 2001).

3.7.3 Ecosystem services and valuation

Sections 3.71 and 3.72 have briefly touched upon the ecosystem services provided by the terrestrial and marine ecosystems. This section provides a brief general discussion on ecosystem services and valuation, which are important from the perspectives of environmental economics or natural resources economics.

Ecosystem services are the benefits that ecosystems provide to humans. The Millennium Ecosystem Assessment (2005a) has categorised ecosystem services as provisioning, supporting, regulating and cultural services. These services have provided the benefits to the humans, as illustrated in Figure 3.8.

The degradation of ecosystems reduces their ability to provide benefits, thus negatively affecting human welfare in a number of ways. Methodologies are available for valuing different types of ecosystem services. Methodologies of valuation of ecosystem services are available, though further improvements are still needed (see Costanza et al., 1997; TEEB, 2010a, 2010b; Grainger et al., 2013; Olsen, 2013; Poulsen, 2013).

Despite the complexity of ecosystems and their interactions with our social and economic systems has made the valuation of all ecosystem services difficult, the valuation of different types of ecosystem services is an important element in the assessment of the economics of the impacts caused by the past and future El Niño events, especially the impacts of prolonged drought and the forest fires induced by drought (see Section 4.9). A systematic and coordinated research in these areas in Malaysia by relevant agencies and research institutes is needed, perhaps with funding from the government.

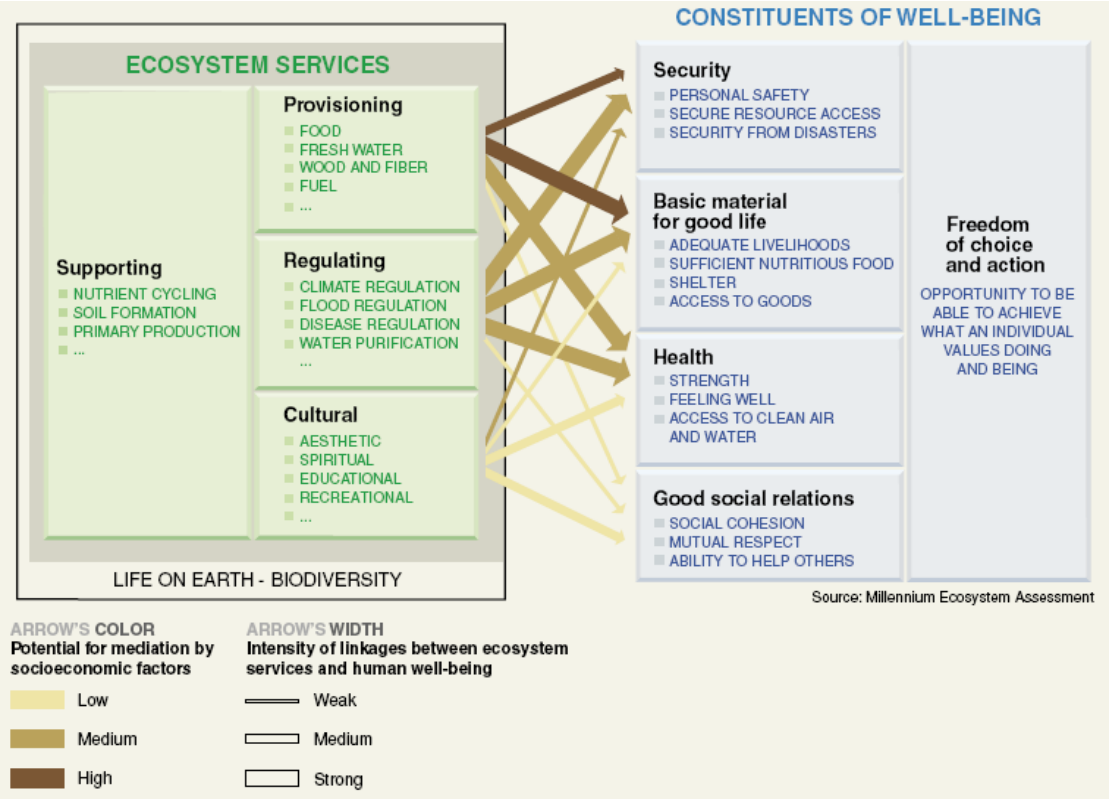


Figure 3.8 Services provided by ecosystems
Source: MEA (2005a)

3.8 Fisheries

There is evidence to show that the 1997/98 El Niño event affected fish migration and fish landing in Malaysia, though the extent was difficult to assess. However, Shahwahid and Othman (1999) estimated that the loss due to the decline in fish landing was RM40.58 million (US$16.23 million) or 5.00% of the total cost of RM801.9 million (or US$321 million at 1997 exchange rate) during the months of August to October (see Section 3.12).

Tawang et al. (2002) and Tawang and Tengku Ahmad (2003) have highlighted the problems faced by aquaculture breeders during the El Niño events. These included (i) the unavailability of water to the pond due to prolonged drought; and (ii) higher water temperature which could affect fish feeding because the fish became less active and avoided the water surface. Consequently, less food was consumed by the fish, resulting in feed wastage, and slower fish growth.

Tawang et al. (2002) investigated the relationship between the level of TSP associated with haze and fish landings during the El Nino events, and found no real link between the two probably due to the short duration of the haze to have any significant effect on annual marine landings. Although technical studies indicate that haze tends to negatively affect the yields of aquaculture farms because of unhealthy air quality that affects the survival rates and weight gain of prawns, fishes and other aquacultural species, Tawang et al. (2002) observed that El Niño events had no significant effect on the annual productivity of both the pool-type and cage-type aquaculture farms.

During the 1997/98 El Niño event, warmer ocean temperature caused widespread coral bleaching in Malaysia. Within South-East Asia, the potential sustainable economic value of coral reefs is substantial. Equally so is the potential economic loss if these resources are degraded, such as reduced productivity of reef fisheries. One estimate puts the value of coral reefs at US$115,740 per hectare per year. This places Malaysia's reefs, with a cover of 4,000km^2, at a value of RM145 billion per year. Economically, coral reef-related businesses in Malaysia have been estimated at approximately US$ 635 million annually, in food, fisheries, tourism and even pharmaceuticals[13]. .

3.9 Air quality

3.9.1 Forest-fires haze

During the 1997/98 El Niño event, especially from July to September 1997, air quality in Malaysia and the neighbouring countries was seriously affected by haze produced by the extensive forest fires in Indonesia. The causes and the impacts of the fires have been comprehensively discussed by Dudley et al. (1997), Schweithelm and Glover (1999), as well as by a recent report prepared by the Haze Task Force established by ASM (ASM, 2016).

About 10 million hectares of forest in Indonesia was destroyed in the 1997/98 haze episode, mostly due to the burning of forests to prepare land for plantation development on peat soil (Jepson et al., 2001; Murdiyarso and Adiningsih, 2007; Saharjo and Munoz, 2005; Suyanto et al., 2004).

The environmental, social and economic impacts of the haze have been well documented (Schweithelm and Glover, 1999; Shahwahid and Othman, 1999; Tacconi, 2003). The haze significantly affected both the natural and human environment, traffic navigation, human health (see Section 3.10), and tourism (see Section 3.11) in Malaysia and in the region.

The Department of Statistics Malaysia, Official Portal only provides Air Pollution Index (API) data at a few selections, namely in Cheras, Kuala Lumpur; Larkin, Johor Bahru;

[13] http://www.reefcheck.org.my/donate

Bandaraya Melaka; Seberang Jaya; Kuching; Kota Kinabalu and Miri since 1998. The air pollutants included in Malaysian's API calculation are Ozone (O_3), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2) and Particulate Matter of less than 10 microns in size (PM_{10}). The index value to indicate the status of the air quality are categorised in Table 3.4.

Table 3.4 Status of the air quality

Value of API	Status
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Very unhealthy
Above 300	Hazardous

Source: Department of Statistics Malaysia, Official Portal: Environment

Table 3.5 Annual maximum and minimum Air Pollutant Index for selected Stations, 1998–1999, Malaysia

Year	Air Quality													
	Air Pollution Index (API)													
	Cheras Kuala Lumpur		Larkin Johor Bahru		Bandaraya Melaka		Seberang Jaya		Kuching		Kota Kinabalu		Miri	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1998	140	10	116	7	92	4	111	16	90	3	459	1	649	6
1999	137	3	114	6	77	3	79	10	76	4	70	1	120	4

(Source: Department of Statistics Malaysia, Official Portal: Environment)

Table 3.5 presents the annual maximum and minimum Air Pollutant Index for seven selected stations, 1998 –1999 in Malaysia. These data reveal that in 1998, the annual maximum API registered 140 (unhealthy) 459 (hazardous) in Kota Kinabalu and 649 (hazardous) in Miri, which were likely to be contributed during the forest-fires-induced haze during the 1998 drought period, as the annual maximum API in 1999 in Kota Kinabalu and Miri had drastically reduced to 70 and 120 (Department of Statistics Malaysia, Official Portal: Environment). Unfortunately, API data for 1997 are not available from the same source for comparison. However, Shahwahid and Othman (1999) reported that the 1997 haze reached new levels of intensity and duration compared to previous events in 1983, 1991 and1992, with API readings reached hazardous levels and a state of emergency was declared for a 10-day period in Sarawak. One report even provided that the API exceeded 800 in Kuching[14].

Mastura Mahmud (2009b) investigated the air quality over a 5-day period from 14 to 17 September 1997. On 14 September 1997 the air quality worsened in Selangor, where average PM_{10} concentrations were →400mg m^{-3}. On 15 September, the neighbouring state Negeri Sembilan was the only one where the high PM10 concentration →400mg m^{-3} persisted. By 16 September air quality improved slightly; Melaka experienced PM_{10} concentrations of →300mg m^{-3} (Mastura Mahmud, 2009b). Interestingly, she found that there was recirculation

[14] http://rainforests.mongabay.com/08indo_fires.htm

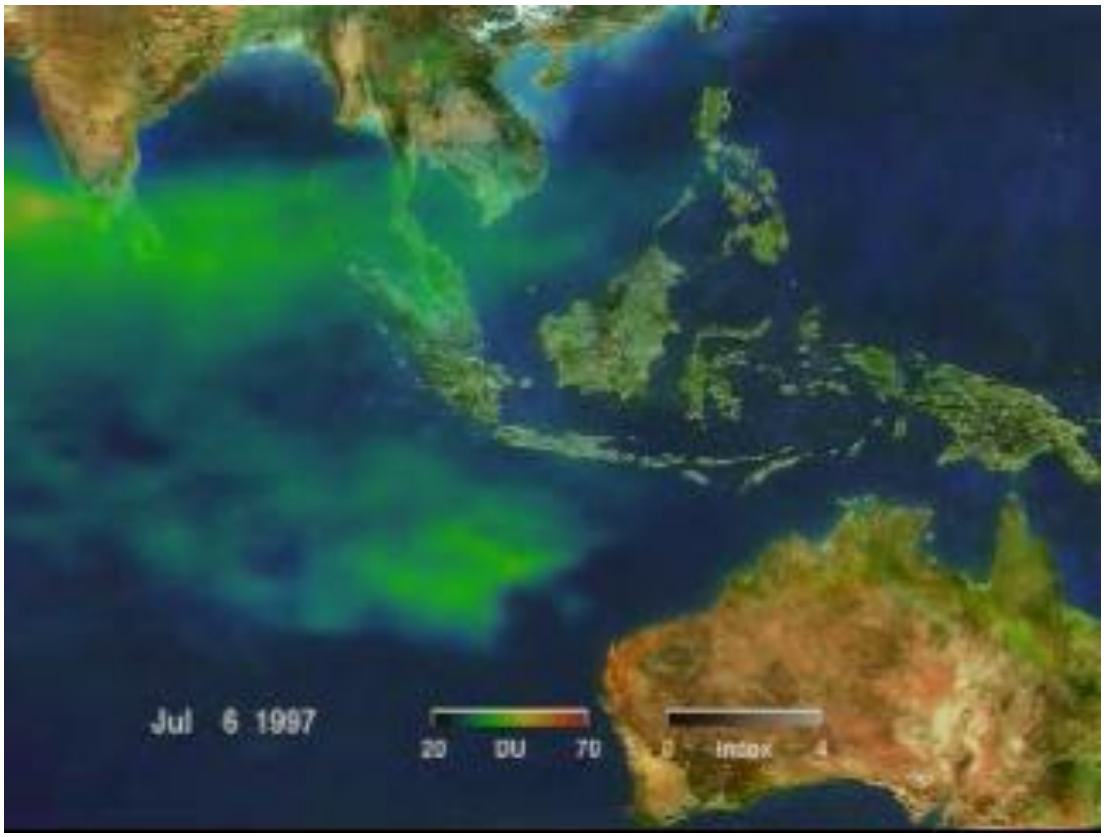
of haze particles which moved towards the shore during the day because of land breeze, and away from the shores during the night because of sea breeze. It is clear that land and sea breezes play an important role in the dispersion of air pollutants in the Klang Valley. More studies on this aspect are needed to assess the air dispersion patterns in the Klang Valley under different synoptic weather conditions during the El Niño events.

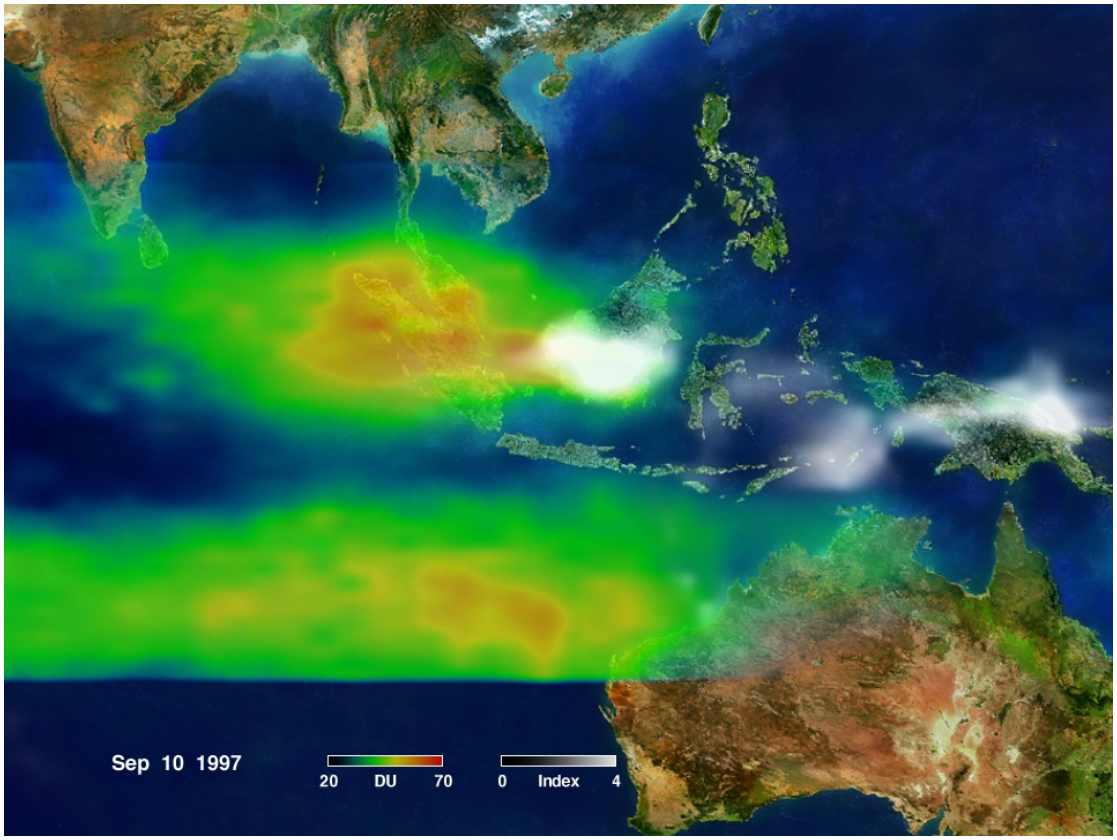
It seems that the API reported is usually based on PM_{10}. It would also be useful to monitor $PM_{2.5}$, which has now been practised by many countries. In addition, API does not provide the synergistic effects of various pollutants, which could be more harmful than the individual impact of one particular pollutant which has the highest API reading.

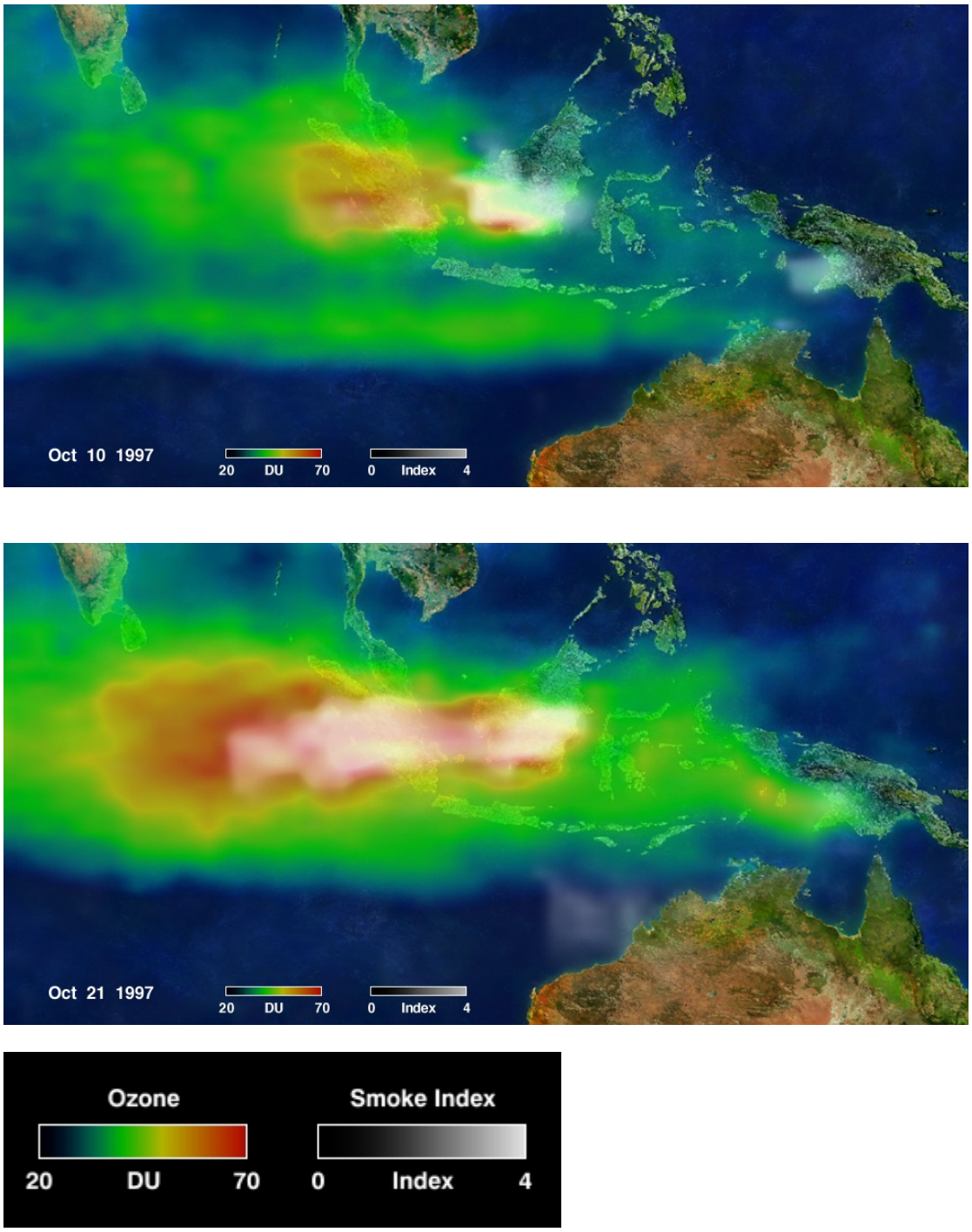
It was estimated that between 0.81 and 2.57 gigatonnes (Gt) of carbon were released to the atmosphere in 1997 as a result of burning peat and vegetation in Indonesia (Page et al., 2002). This is equivalent to 13–40% of the mean annual global carbon emissions from fossil fuels. Indeed, Page et al. (2002) concluded that the 1997 fires were "a major contributor to the sharp increase in atmospheric CO_2 concentrations detected in 1998." Indeed, the carbon dioxide (CO_2) concentration data at Mauna Loa, Hawaii, the baseline station operated by NOAA, showed an increase from 1.22±0.11ppm in 1996 to 1.93±0.11ppm in 1997 and 2.93±0.11ppm in 1998, which was dropped to 0.93±0.11ppm in 1999 (ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_gr_mlo.txt).

Most of the carbon released in the Indonesian fires came not from burning trees but from smoldering peat bogs which lost between 25cm and 85cm of their depth in the fires (Lazaroff, 2002). Apart from CO_2, other emissions from forest fires were nitrous oxide (N_2O) (Ishizuka et al., 2005), a strong greenhouse gas with Global Warming Potential (GWP) of 296 (IPCC 2001 estimation), and an ozone depleter; as well as nitrogen oxides (NO_x), methane (CH_4) and non-methane hydrocarbons, which are precursors for the photochemical production of ozone, an important greenhouse gas (Low 1998; Thompson, 2001; Ishizuka et al., 2005). Methane is also a greenhouse gas with a GWP of 23 (IPCC 2001 estimation).

The tropospheric ozone and aerosol index over Indonesia and Malaysia on 6 July, 10 September, 10 October and 21 October 1997 are shown in Figure 3.9. The significant smog or tropospheric ozone is represented by red and green and regions of significant smoke index are in shades of white and gray. The blanket of pollution spread to the southern part of Thailand and the Philippines, and even stretched as far as to the northern part of Australia.


Jul 6 1997
20 DU 70
Index


Sep 10 1997
20 DU 70
0 Index 4



Source: http://svs.gsfc.nasa.gov/2004 NASA/Goddard Space Flight Center Scientific Visualization Studio

Figure 3.9 The tropospheric ozone and aerosol index over Indonesia and Malaysia on 6, July 10 September, 10 October and 21 October 1997, respectively

In response to this human-induced disaster, ASEAN initiated a Regional Haze Action Plan (RHAP). As part of this Action Plan, a monitoring and warning system for forest/vegetation fires was developed and implemented, namely the Regional South-East Asia Fire Danger Rating System (SEA FDRS), adopted from the Canadian Forest Fire Danger Rating System. The daily responsibility of producing the SEA Fire Danger Rating (SEA FDR) was handed over to the MMD by the Canadian Forest Service (CFS) in mid-September 2003. Since then, the MMD has been producing SEA FDR products on a daily basis to be used to

predict fire behaviour and to guide policy makers in developing actions to protect life, property and the environment.

The ASM Haze Study Group has just completed a comprehensive study on the transboundary haze issues (ASM, 2016). The report assesses the causes of the forest fires-induced haze, and its environmental (including climatic), social and economic impacts, with a view to providing solutions for future actions.

3.9.2 Composition of biomass burning haze

Biomass combustion is an important primary source of many trace substances that are reactants in atmospheric chemistry and of soot particulate matter that decreases visibility and absorbed incident radiation. Chemically, biomass smoke particles contain thermally unaltered and partially altered biomarker compound from the vegetation and can change climate by altering the radiation balance (von Hoyningen-Huene et al., 1999). The atmospheric impact of these emissions is controlled by the type, location, strength and duration of the burning source, and also by their subsequent vertical distribution with implications for their atmospheric transport and chemistry (Monks et al., 2009).

Results from the study by Siao et al. (2007) in three sampling stations in Sumatra, Indonesia, showed that apart from black carbon, anions (SO_4^{2-}, NO_3^-), cations (K^+, $Na^{+)}$ and trace metals were present in atmospheric aerosols during biomass burning. High ionic content in biomass burning, especially from plant materials, may be related to the characteristics of the ecosystem where the trees have grown (Gonçalves et al., 2010). Study by Liu et al. (2000) indicated that major inorganic fine particle types that were emitted during the flaming phase of forest fires consist of pure compounds of KCl and NH_4Cl. Acidification reaction with SO_2 with various sources including the biomass burning increase the concentration of K-Sulfate and NH_4-Sulfate in atmospheric aerosols within rather short distance from fire.

Combustion from biomass burning during haze episode also found to distribute the amount of carcinogenic substances such as polycyclic aromatic hydrocarbon (PAH) (Shen et al., 2013). According to Reisen and Brown (2006), PAH levels achieved more than 30 times higher than the level normally measured during haze episode in several part of Indonesia. In Kuala Lumpur, PAH measurements were recorded more than eight times higher during haze compared to non-haze days (Omar et al., 2006). Benzo(a)pyrene as one of the most toxic PAHs were recorded 15 times higher during haze episode. Further study by Siao et al. (2007) shows that Phenanthrene is the dominant PAH molecules in atmospheric aerosols during haze episode in Sumatra. Ind/Ind + BPe of PAH ratio value during haze episode in Sumatra (0.62 – 076) indicate the biomass burning contribute to the amount of PAH in atmospheric aerosols during haze episode.

3.9.3 Photochemical haze

It may be noted that not all haze aerosols were created by forest fires. It is likely that during dry and hot conditions, photochemical haze could also be produced locally under the sunlight with emissions from motor vehicles and industry. Photochemical haze could also be transported from neighbouring regions. Ozone is the important component of photochemical haze (Low, 1998).

It is most likely that the haze episode Malaysia and neighbouring countries have experienced during the outbreak of forest-fires in an El Nino event could be a combination of both transboundary forest-fires haze and the locally produced photochemical haze. The contribution of forest-fire haze and the photochemical haze and their synergistic effects in any haze episode needs to be scientifically assessed.

3.10 Health

El Niño events could affect human health in many ways. The direct impact would be the heat stress as a result of higher air temperature. For example, Tawang and Tengku Ahmad (2002) reported that during the 1997/98 El Niño event, the monthly temperature increases ranged between 0.1°C and 1.9°C (with the mean at 0.9°C) in Kedah and between 0.1 °C and 2.4°C (with a mean of 1.36°C) in Perlis. The maximum and minimum temperatures were also higher during the El Niño years compared to those of normal years.

The poor air quality caused by continuous hazy conditions affect the health of all, especially high-risk groups such as children, senior citizens and people who smoke, people who work outdoors or sufferers of asthma, bronchitis, pneumonia, chronic lung diseases, cardio-vascular problems or allergies, as identified by Shahwahid and Othman (1999). It has been estimated that for the period from August to October 1997, the total cost related to treatment of the 1997 haze-related illnesses, which included both at the private and government hospitals and clinics and for self-treatment, was RM21.02 million (US$8.408 million) (Shahwahid and Othman, 1999). However, the costs of the long-term effects on health caused by the haze were not included in the above study. If the adverse effects of drought (i.e., not only haze) on health were taken into account, the costs will be more difficult to quantify in part because many of the adverse effects may only be felt for years to come (Hughes et al., 1998).

A 14% decrease in lung function in school children during the 1997 haze was reported (Brauer, 1998; WHO, 1999). Recent study by Sahani et al. (2014) also claimed that biomass burning in South-East Asia caused haze exposure with immediate and delayed effects on mortality. A good example is the haze episode in the Klang Valley, Malaysia, between 2001 to 2010, that was responsible for an immediate effect of respiratory mortality with a 19% increment for all respiratory mortality, and 34% and 41% increments in respiratory mortality for all males and elderly male residents respectively. Delayed effects of haze were found in cases of natural mortality of children and respiratory mortality of adult females aged 15–59 years old, with incremental of 41.4% and 66% respectively. Another study by Othman et al. (2014) showed that haze occurrence was associated with an increase in inpatient cases by 2.4 per 10,000 populations each year, representing an increase of 31% from normal days. The average annual economic loss due to the inpatient health impact of haze was valued at RM273,000.

In addition, haze affects the degree of sunshine hours in the region (Tawang et al., 2002). The blockage of sunlight during haze episode may promote the spread of harmful bacteria and viruses that would otherwise be killed by ultraviolet B radiation (Afroz et al., 2003).

The outbreak of the Nipah Virus (NiV) spread by fruit bats, which was reported to have been first identified in Kampung Sungai Nipah, Malaysia, in 1998, could be linked to the 1997/98 El Niño event. According to Looi and Chua (2007), it was probable that "initial transmission of NiV from bats to pigs occurred in late 1997/early 1998 through contamination of pig swill by bat excretions, as a result of migration of these forest fruit bats to cultivated orchards and pig-farms, driven by fruiting failure of forest trees during the El Nino-related drought and anthropogenic fires in Indonesia in 1997-1998".

It was clear that the Malaysian government was unprepared for this new disease and subsequently bore high costs from the outbreak, including more than 100 human lives lost, as well as an economically devastating collapse of its pig-farming industry. Before the outbreak, Malaysia had 2.4 million pigs, of which approximately 1.1 million of them had to be culled, costing about US$97 million. Compensation paid to farmers cost the government up to US$35 million. In addition, the export of pigs to Hong Kong and Singapore was halted, resulting in a loss exceeding US$100 million in trade for Malaysia. In total, the outbreak cost the Malaysian government more than US$450 million. Of great concern too

was the impact on livelihoods. Although the government provided free public health care to patients - many of whom required intensive care during the initial stages of the illness - which protected the affected families from destitution, most of the pig farms were family-run businesses that provided income and stability for entire communities. The collapse of the industry therefore had a severely negative impact on these people (Kahn, 2011).

Malaysia first documented dengue in 1902 and the disease was made notifiable in 1973 (George and Lam, 1997). World Health Organization (WHO) reported that during 1997/98, Malaysia recorded an increase in dengue incidence, with 19,544 dengue cases in 1997 (the highest since 1973), which was 37.4% higher than the number reported in 1996. Among these cases, 806 were dengue haemorrhagic fever resulting in 50 deaths. Cases were reported throughout the year but peaked in July 1997, and most cases were reported in urban areas with high population density (WHO, 1998). It is likely that several factors might have affected the disease patterns, including the prolonged drought caused by the 1997/98 El Niño event that could affect vector density, as well as the economic downturn during the time that greatly reduced the construction activities which were previously associated with dengue outbreaks (WHO, 1998).

In addition, during the 1997/98 El Niño event, significant outbreaks of cholera were reported in Malaysia, as well as in Indonesia and the Philippines. These outbreaks were linked primarily to the lack of clean drinking water associated with the severe El Nino-related drought (Harvard Medical School, 1999).

3.11 Tourism

When the Malaysian economy was hit by the regional haze crisis during late 1997, tourism along with leisure and restaurant businesses suffered profoundly. The Bank Negara Malaysia (1997) reported that the prolonged haze severely affected tourist arrivals and related services receipts during the months of July-October 1997. For example, "the occupancy rates of hotels dropped from a norm of 60-65% to as low as 30-50% for some hotels in the Kuala Lumpur Golden Triangle area". The negative reports on the haze situation contributed to this tourist decline.

According to the Tourist Development Corporation of Malaysia, tourism sector saw a decreased number of international visitors arrival in Malaysia from 7.14 million in 1996 to 6.21 million in 1997 (or a decline by 13%) and 5.55 million in 1998 (or a decline by 22.3%), before the number increased to 7.93 million in 1999 (Table 3.7). Similarly, there was a decrease in tourism revenue from RM10.35 billion in 1996 to RM9.70 billion in 1997 and RM8.58 billion in 1998, before an increase to RM13.45 billion in 1999 (Table 3.6).

Table 3.6 International tourist arrivals and receipts to Malaysia

Year	Arrivals (million)	Receipts (RM billion)
1990	7.45	4.50
1991	5.85	4.30
1992	6.02	4.60
1993	6.50	5.07
1994	7.20	8.30
1995	7.47	9.17
1996	7.14	10.35
1997	6.21	9.70
1998	5.56	8.58
1999	7.93	13.45
2000	10.22	17.34
2001	12.78	24.22
2002	13.29	25.78
2003	10.58	21.29

Source: Annual Statistics Report, Tourism Malaysia as cited in Salleh et al. (2007)

Tourists arrival and the tourism expenditure received from 1990 to 2003 are shown in Figure 3.10. There was a significant decrease in both the tourists arrival and the expenditure received during the 1997/98 El Niño event. It is interesting to note that similar decrease in both the tourists arrival and the expenditure received also occurred during 2002/03, another El Niño event that was not as strong as the 1997/98 El Niño event.

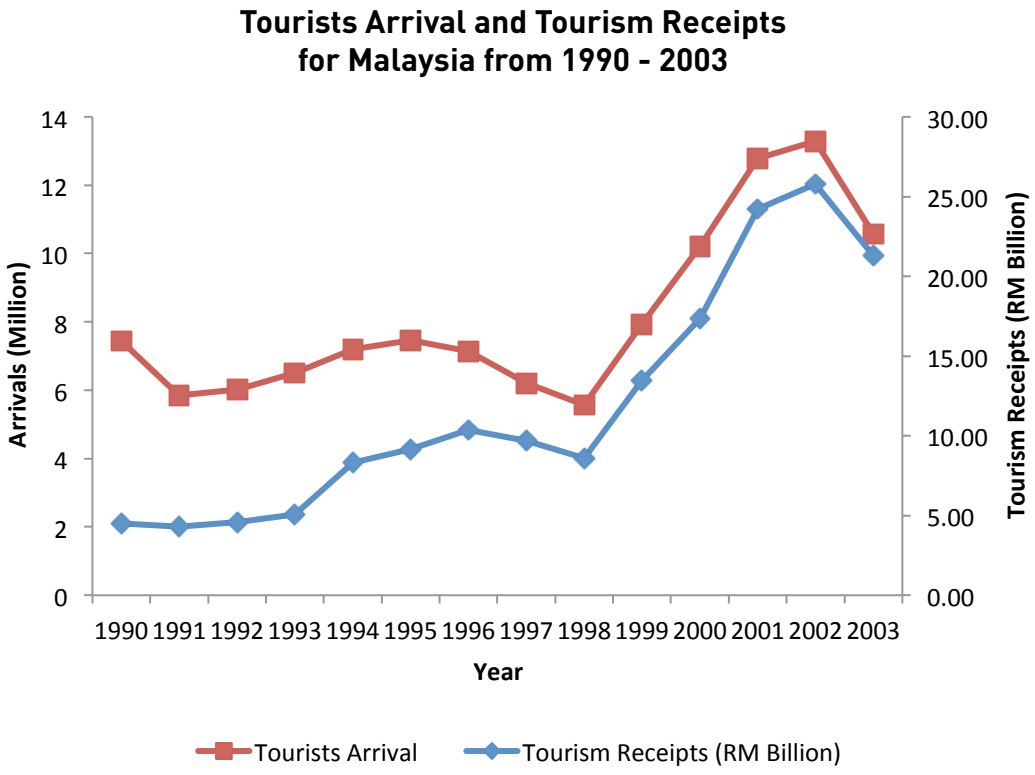


Figure 3.10 International tourists arrival and expenditure in Malaysia, 1990-2003, respectively. Both significant decreases in tourists arrival and tourism receipts occurred during the 1997/98 and 2002/03 El Nino events

Source: http://corporate.tourism.gov.my/research.asp?page=facts_figures

Bank Negara Malaysia (1997, 1998) also reported that in 1997, "the performance of the tourism industry was affected particularly by the prolonged haze in the South-East Asian region. The net surplus in the travel account declined by almost RM1 billion to RM3.8 billion, the first decline since 1991. The decline in tourist arrivals by 13% to 6.2 million more than offset the increase in average per capita expenditure of 8.2%. Average per capita expenditure rose during the year as per diem expenditure of tourists increased by 9.6%, while the length of stay of tourists per visit stood at 5.3 days (1996: 5.4 days). The number of excursionist arrivals also declined by 8.1%. Consequently, the combined earnings from various categories of travellers, namely tourists (who stayed more than one day), excursionists (day travellers) and transit passengers, declined by RM740 million to RM10.5 billion. "

"In 1998, the regional economic downturn affected the performance of the tourism industry. The net surplus in the travel account fell to RM3.1 billion, representing an annual decline of 13.6%. Tourist arrivals fell for the third consecutive year, by a further 10.6% to 5.6 million, below the initial official target of 6.8 million visitors for the whole of 1998. Average per capita expenditure of tourists also declined, albeit at a marginal rate of 1%, due primarily to a 5% reduction in per diem expenditure as the length of stay of tourists per visit

increased to 5.5 days (1997: 5.3 days). Similarly, the number of excursionist arrivals also dropped by 16.4%. As a result, the combined earnings from tourists (who stayed for more than one day), excursionists (day travellers) and transit passengers, fell by RM1.2 billion to RM9.3 billion".

One would expect international tourists to take advantage of the economic downturn that occurred at the same time in Malaysia during 1997-1998. However, this was clearly not the case as the prolonged haze had driven a significant number of international tourists away, while those tourists from the neighbouring countries were reluctant to travel not only because of haze, but also because of the economic downturn in their own countries.

3.12 Education

During the 1997/98 El Niño event, severe haze episodes disrupted children's education and school activities. Parts of Sarawak were under a state of emergency at the height of the crisis, forcing schools to close for periods of days to weeks (Schweithelm and Glover, 1999). It is noted that in Singapore, a 24-hour response plan based on Pollutants Standard Index (PSI) was put in place by the Ministry of Education (MOE) and Sports Council, under the Haze Action Plan, to close schools and sports complexes (Hon, 1999).

Shahwahid and Othman (1999) reported that the corporates such as The Star and Dupont Malaysia launched a campaign to create awareness among school children for the need to wear masks during the haze period. Under this campaign, 20,000 masks were distributed to selected schools in areas where the API was the highest on the peninsula (i.e., Gombak, Nilai, Penang, Kuala Lumpur, and Petaling Jaya). A large number of masks - 300,000 were donated by the Federal Government, 20,000 by the United Nations Children's Fund (UNICEF), and 10,000 by the Japan International Cooperation Agency (JICA), were also sent to Sarawak, reflecting the emergency situation in the state. However, the masks may not be effective enough for filtering submicron particles.

3.13 Social and economic costs of haze

From October 1997 to May 1998, the Economy and Environment Program for Southeast Asia (EEPSEA) and the World Wide Fund for Nature (WWF) Indonesia conducted a quick assessment and valuation of the damages caused by the fires and haze in Indonesia, Malaysia and Singapore (Glover and Jessup, 1999). The assessment report was prepared while the fires of 1998 were still raging. It assessed the damages during the first outbreak of fires in 1997. As only the damages for 1997, not 1998, were assessed, the total damages for the entire 1997/98 El Niño-related event were considerably higher than those reported. Furthermore, the study did not attempt to value every possible damage. For example, data were unavailable in some cases, while in others, there was no widespread agreement, even among economists, on estimation methods. This is particularly true for damages such as loss of life or biodiversity. As a result, a large portion of the cost associated with the fires and haze was omitted in the study, so the estimates presented were largely conservative "lower bounds" figures. In reality, the damages could be considerably higher. Even the editors of the study report admitted that the assessed damage of about US$4.5 billion was "conservative" (Glover and Jessup, 1999).

Despite the shortcomings, the damage estimates were significant. The assessment covered losses from fire, such as damage to timber, agriculture, a wide range of direct and indirect forest benefits, capturable biodiversity (for Indonesia only), fire-fighting costs, and release of carbon dioxide that affects climate change; and from haze, short-term health costs, tourism losses and some losses in production. The estimates are provided in Tables 3.7-3.9 beside.

Table 3.7 Fire- and Haze-Related Damages from the 1997 Indonesian Forest Fires (US$ millions)

Type of Loss	Loss to Indonesia	Loss to Other Countries	Total
1. Fire-related damages			
Timber	493.7	—	493.7
Agriculture	470.4	—	470.4
Direct forest benefits	705.0	—	705.0
Indirect forest benefits	1,077.1	—	1,077.1
Capturable biodiversity	30.0	—	30.0
Fire-fighting costs	11.7	13.4	25.1
Carbon release	—	272.1	272.1
Sub-total	2,787.9	285.5	3,073.4
2. Haze-related damages (summary)			
Short-term health	924.0	16.8	940.8
Tourism	70.4	185.8	256.2
Others	17.6	181.5	199.1
Sub-total	1,012.0	384.1	1,396.1
Total damages	3,799.9 (85%)	669.6 (15%)	4,469.5

Note: Where Asian currency values were used, they were converted to U.S. dollars at the July 1997 exchange rates of US$1 = Rp2,500/RM2.5/S$1.4.

Fires and haze affected 5 million hectares in Indonesia and 70 million people throughout the region.

Agriculture losses: include those to plantations and smallholdings. They do not include possible haze damage via reduced photosynthesis, pollination, and so on.

Direct forest benefits: include non-timber forest products such as food, local medicines, raw materials, and recreation.

Indirect forest benefits: include storm protection, water supply and regulation, erosion control, soil formation, nutrient cycling, and waste treatment.

Capturable biodiversity: refers to the potential income lost to Indonesia from international conservation expenditures, i.e., the amount that international agencies and NGOs have shown they are willing to pay to conserve tropical forests. It does not reflect the intrinsic value of species whose extinction has been hastened, the potential value of ecotourism or internationally marketed pharmaceuticals, the human cultural diversity of indigenous forest-based cultures, or other benefits too difficult to value. These losses are shared by Indonesia and the rest of the world.

Carbon release: the release of carbon from fires will contribute to climate change, which will in turn result in economic damage. This figure reflects the amount of damage that the 1997 release is expected to cause.

Haze-related damages not estimated here include long-term health damages, reduced crop productivity, aesthetic value of reduced visibility, avertive expenditures, accidents, loss of life, evacuations, and loss of confidence by foreign investors.

Source: Schweithelm et al. (1999)

Table 3.8 Haze-related damages arising from the 1997 forest fires, in detail (millions)

Type of Damage	Indonesia		Malaysia		Singapore		
	Rp*	US$*	RM*	US$*	S$*	US$*	Total US$
Short-term health damages	2,310,000	924	20.1	8.0	12.5	8.8	940.9
Industrial-production losses	U	U	393.5	157.4	N	N	157.4
Tourism losses	176,000	70.4	318.5	127.4	81.8	58.4	256.2
Airline and airport losses	44,000	17.6	0.5	0.2	9.7	6.9	24.7
Fishing decline	U	U	40.6	16.2	N	N	16.2
Cloud seeding	U	U	2.1	0.8	N	N	0.8
Total	2,530,000	1,012	794.3	310.0	104.0	74.1	1,396.1

Note: Damages exclude long-term health damages, reduced crop productivity, aesthetic value of reduced visibility, avertive expenditures, accidents, loss of life, evacuations, and loss of confidence by foreign investors. Small discrepancies in totals reflect rounding off.

* In July 1997 the exchange rates were US$ = Rp2,500/RM2.5/S$1.4.

N = negligible or not applicable
U = unknown: data unavailable

Source: Schweithelm et al. (1999)

Table 3.9 Aggregate value of haze damage from August to October, 1997, Malaysia

Type of Damage[1]	RM Million	US$ Million	Percentage
Adjusted cost of illness	21.02	8.41	2.62
Productivity loss during the state of emergency	393.51	157.40	49.07
Decline in tourist arrivals	318.55	127.42	39.72
flight cancellations	0.45	0.18	0.06
Decline in fish landings	40.58	16.23	5.00
Cost of fire-fighting	25.00	10.00	3.12
Cloud seeding	2.08	0.83	0.26
Expenditure on masks	0.71	0.28	0.09
Total damage cost	801.90	321.00	100.00

Source: Shahwahid and Othman (1999)

Shahwahid and Othman (1999) provided a comprehensive estimate of economic losses in Malaysia associated with the 1997 haze episode for three months during the months of August to October (Table 3.9). They estimated that the total damage cost was RM801.9 million (or US$321 million at 1997 exchange rate), mainly contributed by the loss in productivity during the state of emergency in Sarawak from 19 to 28 September, which accounted for 49.07%; followed by decline in tourists arrival, which accounted for 39.72%; and decline in fish landing, RM40.58 million (US$16.23 million) or 5.00%; cost of fire-fighting, RM25 million (US$10 million) or 3.12%; adjusted cost of illness RM 21.02 million (US$8.41 million) or 2.62%; cloud seeding, RM2.08 million (US$0.83 million) or 0.26%; expenditure on masks, RM0.71 million (US$0.28 million) or 0.09%; and cancellation of flights, RM0.45 million (US$0.18 million) or 0.06%, respectively.

It was reported that the cost of the haze could have been used to finance various social projects and poverty alleviation–related programmes, as well as environmental

conservation and biodiversity programmes which were planned by the government (e.g., Kuala Selangor Nature Park) (Shahwahid and Othman, 1999).

Malaysia's total cost of damage was about 3.3 times lower than that of Indonesia, but 4.2 times higher than that of Singapore (Table 3.7).

However, the above estimate was very conservative, as the damages excluded "long-term health damages, reduced crop productivity, aesthetic value of reduced visibility, avertive expenditures, accidents, loss of life, evacuations, and loss of confidence by foreign investors". In addition, the above estimation did not include economy-wide costs (see Section 3.14). It also did not include the valuation of ecosystem services, including the cost of the long-term effects on the fragile terrestrial ecosystems which are difficult to quantify; the cost of destroyed biodiversity, the cost of climate change as a result of the emission of greenhouse gases, and the cost of land degradation as a result of extensive damage to land. The fire-affected fragile ecosystems would take many years to recover (Hughes et al., 1999). The effects of haze on plant life were not assessed. Choong (1997) found that leaden sky reduced flowering and fruiting in plants. Crops affected included rice, fruit, and vegetables (Shahwahid and Othman, 1999).

The monetary costs of the widespread and often serious impacts on health caused by the drought will be more difficult to quantify in part because many of their effects will be felt for years to come.

With more data and new valuation methodologies, including the improved methodologies for the valuation of ecosystem services, it would be useful to reassess the above study undertaken by Shahwahid and Othman (1999), not only for the period of August-October 1997, but also extending the period of the study to March or April 1998 after the disappearance of the forest fires haze. Better still, it would be very useful if the total cost due to drought over the whole period of the El Niño event (i.e., from February 1997 to April 1998) can be estimated (see Sections 3.14 and 3.15).

3.14 Economy-wide costs

While the direct and indirect costs attributable to the 1997/98 El Niño-related events (drought, forest fires, haze) may be largely estimated within limits of uncertainty, these two costs can, through a complex chain of influences, lead to a multitude of other costs throughout an economy. For example, rainfall deficit could lead to a decrease in agricultural and industrial productivity, which eventually could affect the export earnings and the number of employment. These could, in turn, lead to a series of "knock-on" effects throughout the economy by affecting the circulation of income and international trade flows. Grainger et al. (2013) discussed the economy-wide costs as a result of land degradation. Similarly, it would be useful to estimate the economy-wide costs of the 1997/98 El Niño event, and indeed, for any El Niño events in the future.

3.15 GDP in 1997-1998

The GDP figures in Malaysia from 1990 to 2003 are provided in Table 3.10 and plotted in Figure 3.11.

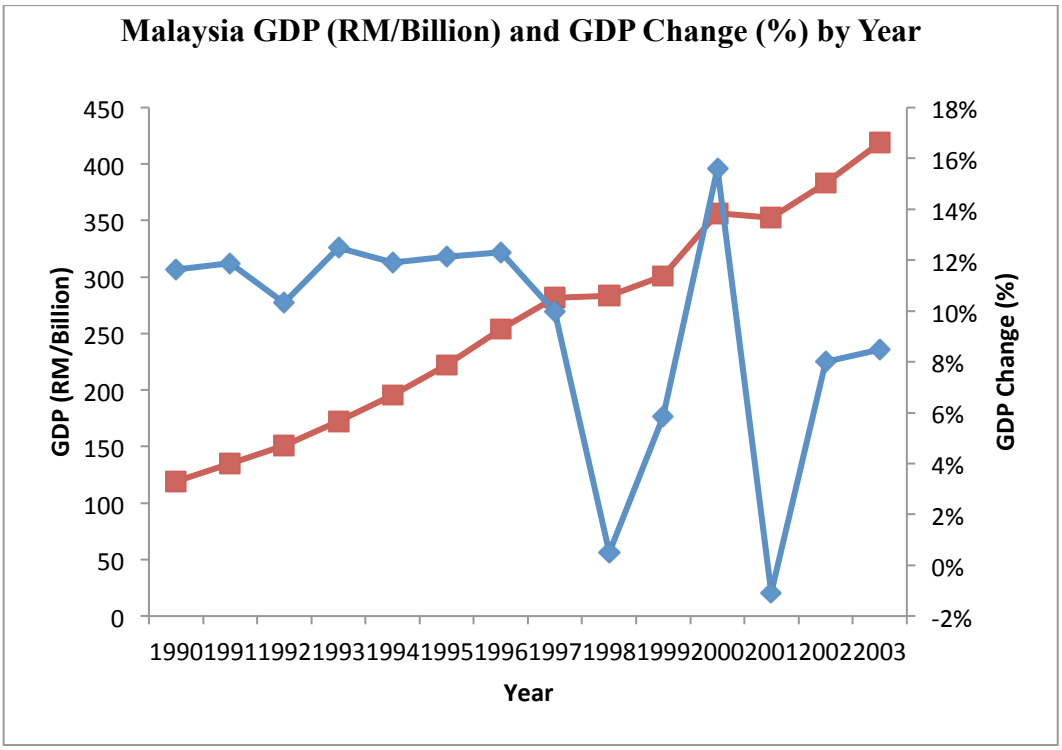
The GDP showed a decline from 1997 to 1998 due to the regional financial crisis during these two years. However, the loss of productivity in key economic sectors as a result of the impacts of the 1997/98 El Niño event was likely a contributing factor.

Table 3.10 GDP in Malaysia for 12 years (1990-2003)

	1990	1991	1992	1993	1994	1995	1996
GDP (RM/billion)	119.081	135.124	150.682	172.194	195.461	222.473	253.732
GDP (% change)	11.63	11.87	10.33	12.49	11.9	12.14	12.32

	1997	1998	1999	2000	2001	2002	2003
GDP (RM/billion)	281.795	283.243	300.764	356.401	352.579	383.213	418.769
GDP (% change)	9.96	0.51	5.83	15.61	-1.08	7.99	8.49

Source: Department of Statistics, Official Portal,
https://www.statistics.gov.my/index.php?r=column/ctimeseries&menu_id=NHJlaGc2Rlg4ZXlGTjh1SU1kaWY5UT09



Source: Department of Statistics Malaysia, Official Portal,
https://www.statistics.gov.my/index.php?r=column/ctimeseries&menu_id=NHJlaGc2Rlg4ZXlGTjh1SU1kaWY5UT09

Figure 3.11 GDP and percentage change in GDP compared to previous year in Malaysia for 1990 to 2003

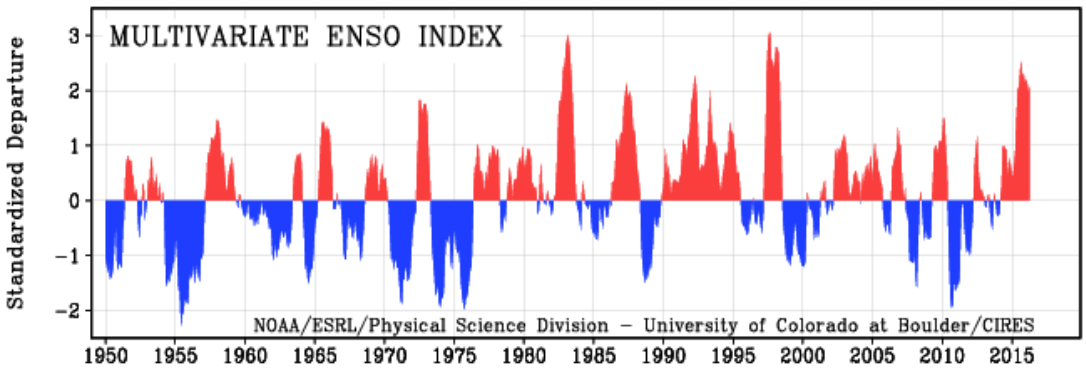
The percentage change in GDP compared to the previous year is also calculated and provided in Table 3.10 and plotted in Figure 3.11. It is clear that there was a significant percentage change from 1997 to 1998.

Indeed, Bank Negara Malaysia (1997) reported that GDP remained strong at 8.5% during the first half of 1997, but moderated to 7.1% during the second half of 1997. In 1998, the full effect of the regional financial crisis on the Malaysian economy was felt, and the real GDP declined by 6.7% (Bank Negara Malaysia, 1998). In particular, the GDP had a -4.0% for agriculture, forestry and fishery, a -10.2% for manufacturing and a -24.5 % for construction in 1998. In 1999, economic activity in Malaysia rebounded from a contraction of 7.5% in 1998 to record a strong positive growth of 5.4%. The value of GDP has returned to almost the same level as in 1997 (Bank Negara Malaysia, 1999).

Chapter 4: Coping with El Niño: Lessons learned from the 1997/98 El Niño event

4.1 Drought and drought risk reduction

Drought[15] is an extreme climatic event, often described as a "natural" hazard, though it is now increasingly clear that human activities could exacerbate this hazard. For example, human-induced climate change could cause the shift in seasonal and latitudinal precipitation patterns, as well as an increase in extreme weather events (though there may have regional variations), both of which could have significant implications for drought. The regional precipitation patterns can also be influenced by the distribution of air pollutants (aerosols), as evidenced by the "atmospheric brown cloud" (Ramanathan et al., 2005).



Outline for MEI webpage (updated on May 6th, 2016)

Figure 4.1 Multivariate ENSO index since 1950. The "El Niño" warm phase (red spike areas) and the "La Niña" cold phase (blue spike areas) of the ENSO phenomenon are indicated (Source: NOAA Climate Diagnostics Center[16].

There is evidence to suggest that the frequency, persistence and magnitude of El Niño events seem to have increased in the last 40 years, as indicated by the multivariate ENSO Index, an index of six observed variables (i.e., pressure, air and sea-surface temperatures, zonal and meridional winds, cloudiness) over the tropical Pacific, which is used to monitor the coupled ocean-atmosphere phenomenon known as the ENSO (Figure 4.1). This trend is projected to continue.

El Niño induces drought in western Pacific, including the South-East Asian region, as well as many other parts of the world (see Chapter 2). Indeed, Cook et al. (2010), based on tree-ring samples, provides evidence of at least four epic droughts that have shaken Asia over the last thousand years, including one that may have helped bring down China's Ming Dynasty in 1644 because of peasants' rebellions. They also observed a mega-drought in the wider region around Angkor from the 1340s to the 1360s, followed by a more severe but

[15] Drought is generally defined as "a deficiency of precipitation over an extended period of time, usually a season or more, which results in a water shortage". However, droughts may be classified as (a) Meteorological drought, which is usually "defined by a precipitation deficiency over a pre-determined period of time" (e.g., 50% of normal precipitation over a six-month period; (b) Agricultural drought, which is "defined more commonly by the lack of availability of soil water to support crop and forage growth"; (c) Hydrological drought, which is "normally defined by deficiencies in surface and subsurface water supplies relative to average conditions" at various time through the seasons; and (d) Socio-economic drought "reflects the relationship between the supply and demand for some commodity or economic good (such as water, livestock forage, or hydroelectric power) that is dependent on precipitation. See UNISDR (2009).

[16] http://www.cdc.noaa.gov/people/klaus.wolter/MEI/

shorter drought from the 1400s to 1420s. It would be interesting to trace if these droughts were linked to the historical El Niño events[17].

Apart from El Niño, monsoon failure could also have implications for drought in the South-East Asian region. Some studies suggest that El Niño often coincides with a weak monsoon and drought (Cook et al. 2010; Ummenhofer et al., 2013).

However, drought by itself does not trigger an emergency that requires immediate relief. Whether it becomes an emergency depends on its impact on local people and the environment, which, in turn, depends on their vulnerability and resilience to such a 'shock' (Wilhite, 2000; UNISDR, 2003).

[17] http://www.sciencedaily.com/releases/2010/04/100422153929.htm

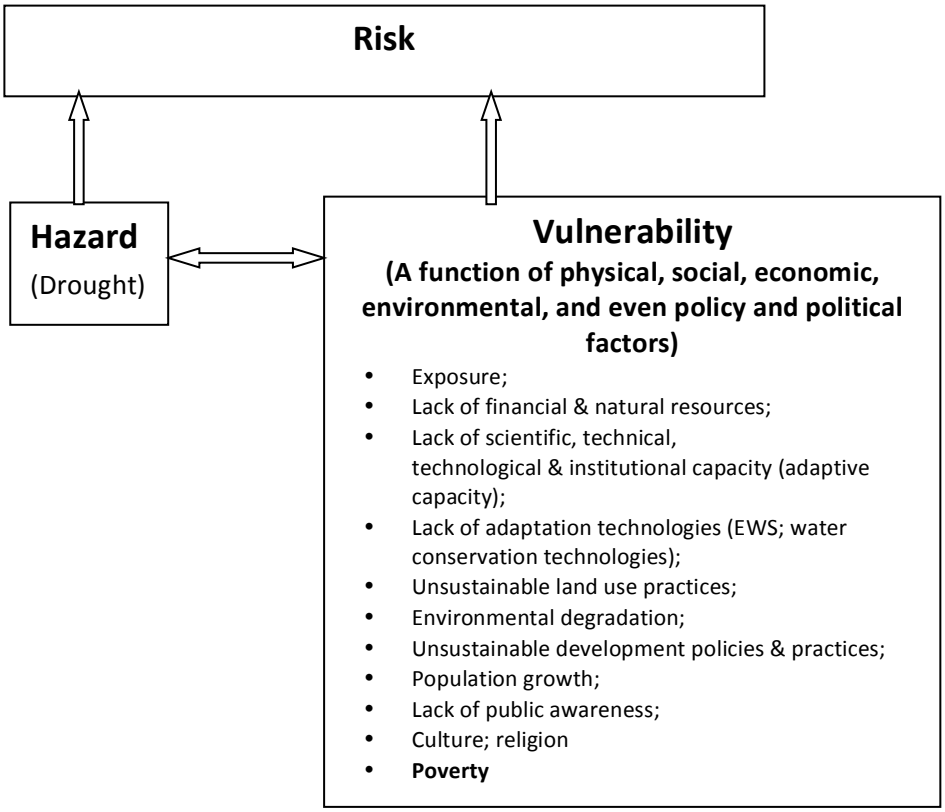


Figure 4.2 Relation between hazard (drought), vulnerability and risk. This figure is based on the conceptual frameworks as presented in Figure 1.4 and Figure 1.6 in Birkmann (2006) but with modifications

As shown in Figure 4.2, vulnerability is a function of many parameters, including physical, social, economic, environmental and even policy and political factors. To reduce drought risk, it is important to identify and minimise the factors that contribute to the reduction of the vulnerability of a country to drought. These factors could be related to the duration of exposure, as well as environmental (including natural ecosystems that provide the environmental services), social, economic, technical, technological and political (including policy). For example, a country with an intact natural ecosystem is likely to be more resilient to drought risks. Similarly, a country with effective policies and more financial and technological resources (e.g., an effective early warning system) for mitigation and adaptation (including drought preparedness), is more able or more resilient, and hence less vulnerable, to the adverse effects of drought. Strengthening of coping or adaptive capacity is crucial in ensuring a drought-resilient society or a society with reduced risk to the adverse effects of drought. Poverty could be an important factor that makes poor people more vulnerable to drought because they have fewer resources for coping in adapting to drought. Similar concept has been discussed by Low (2010) in terms of vulnerability of a society to climate change, in which drought will be a common feature in the future.

4.2 Lessons learned

Although no two El Niño events are exactly the same or even closely similar in their global, regional or national characteristics or effects (Hughes et al., 1998), a number of lessons can still be learned from the impacts of the 1997/98 El Niño event in Malaysia. This will prepare us to better cope with future El Niño events, as well as any drought events induced by climate change which is less predictable. The lessons include scientific, technical and technological aspects, including valuation of environmental, social and economic impacts, as well as national policies that are conducive to reducing the vulnerability of both natural and human environments to future El Niño events. Public awareness also plays an important role in contributing to drought preparedness and mitigation, as well as adaptation. The following sections will discuss these aspects.

4.3 The need for scientific, social and economic research

Contrary to the prediction in early 2014, including those by the leading scientific institutions in the world, such as NOAA, IRI and the UK Meteorological Office, the widely expected strong El Niño event had not been developed by the end of the year (see Chapters 1 and 2). This demonstrates that there is still large uncertainty in the long range prediction of El Niño. With monthly updates of the state and forecast of the evolution of the El Niño, the operational outlooks which have been practised in recent years are useful for risk management planning for periods within or less than a season. Additionally, the impacts of El Niño can be expected to prevail and are likely to worsen based on past El Niño events.

It seems that many developing countries, including Malaysia, are closely following the forecasting of El Niño provided by leading scientific institutions in the world. This is understandable given the strong scientific and technical capabilities of these advanced institutions. However, it is also essential for the developing countries, including Malaysia, to develop national scientific and research capabilities, so that the forecasting of El Niño is more relevant and specific to national and local environment for better mitigation and adaptation measures.

While there were some estimates about the social and economic impacts of the 1997-98 El Niño event in certain sectors, we still do not have the whole picture, as seen in Chapter 3. So far the scientific research on the impacts of El Niño on agricultural crops, and on the terrestrial and marine ecosystems has been limited in Malaysia, including the spatial distribution of these impacts, and how these impacts could affect the phonological changes of plants and animal species in the longer term timescale. In view of the changing climate, there is an urgent need to strengthen this scientific research.

Thus, it is essential to map the variations in vulnerabilities and impacts (environmental, social and economic) across various sectors and geographical locations in the country. Based on past El Niño events, which may be classified as weak, moderate and strong events, these variations could be analysed and studied and taken into consideration in addressing the potential impacts of future El Niño events (UNU, 2000).

In order to provide policy makers for better decision-making, much research is also needed to assess the environmental, social and economic costs of prolonged drought induced by the past El Niño events, including the cost of actions versus non-actions.

How could climate change affect the onset, magnitude, intensity and frequency of El Niño? Further research on these aspects is needed to assess the links between climate change and El Niño.

4.4 Prevention and mitigation

Prevention of forest fires and associated haze is always a better solution than mitigation, as it is less costly. In terms of forest fire prevention and mitigation, science and technology covers various aspects, therefore there is a need for an appropriate balance of focus, depending on perceived needs. While most of the skills needed at the field level are to be developed locally, certain sophisticated technology can be acquired through technology transfer. The use of geosynchronous satellites and space-borne sensors for early warning of fires and atmospheric pollution; investigation of candidate systems for weather conducive to forest fires, and fire danger forecasting; assessing influence of inter-annual climate variability; and interpretation of fire scar characteristics are some of the areas where there is need to build national capability.

4.4.1 Technical, technological and infrastructural constraints

During the 1997/98 El Niño event, several factors have aggravated the causes of fires. ADB (2001) has highlighted a number of these causes, which are related to technical, technological and infrastructural constraints. These include "lack of appropriate technology; inadequate knowledge and appreciation about technological possibilities as well as limitations; insufficient tools and equipment; inadequately trained personnel; lack of research support; inadequacies in forest fire management exemplified by lapses in monitoring, fire danger warning, fire protection measures; pre-suppression planning and preparedness, and fire-fighting; and reluctance to adopt zero-burning techniques of land preparation and low impact logging" ; as well as "lack of infrastructure such as access roads, fire corridors, fuelbreaks, observation towers, water reservoirs, communication and mapping facilities, satellite stations, etc.". All of the above factors affect the efficiency of fire management.

4.4.2 Drought monitoring

Historically, the drought monitoring programme in Malaysia was initiated by the DID in 2001 as a result of the 1997/98 drought event. Among its first initiative was the establishment of the website http://infokemarau.water.gov.my to wholly focus on drought monitoring and to act as repository for information. The objective is to assist relevant agencies to make early preparation for the drought events. In 2013, the website was further improved to include additional features to better reflect the drought situation in Malaysia. DID Malaysia is given the responsibility to report on river water and reservoir water level. In this website, it is reported that 21 water-level stations have been set up to monitor reservoirs level and another 23 stations for rivers.

DID uses the Standard Precipitation Index (SPI) and water level in rivers and dams as a tool to monitor hydrological drought. Hydrological drought, as defined in Footnote 1, is the "deficiencies in surface and subsurface water supplies relative to average conditions". A hydrological drought situation would occur when any river discharge reduces or any dam level decreases continuously. This situation can be defined by the changes stated below:

(a) River Discharges low flow exceed 5 years Average Recurrence Interval (ARI) continuously for 3 months, a drought event is considered as occurring. On a daily basis, DID Malaysia reports the 7-day low flow for ARI of 2, 5 and 20 year for 23 stations throughout Peninsular Malaysia and upload the information via its website known as InfoKemarau.

(b) Dam Levels / Storage Dam Drought event would be considered when a dam levels falls below the normal level for 3 months continuously. DID Malaysia reports the water level in 23 dams and include useful information such as maximum water level, percentage of balance of storage, danger and critical level. This information may also be derived from the InfoKemarau. The website proved to be useful reference during the last drought episode. Information on the water level of some of the dams operated by other operators is also

reported online. For comprehensive monitoring of the nation's water supply, an integrated dam level information hub is necessary.

In recent years, a more coordinated mechanism for monitoring of drought has evolved where three main agencies namely the MMD, the DID and the Department of Minerals and Geoscience Malaysia (JMG) are entrusted with the task of monitoring drought. The MMD uses the SPI and rainfall anomalies to reflect the drought severity in Malaysia. It will issue drought early warning if there is possibility of drought based on weather and climate forecasting tools including numerical modelling and related index which indicate early signs of drought due to certain phenomena such as El Niño.

However, it may be noted that predictive models sometimes could prove unreliable, so other efforts must be made to monitor the onset and the development of drought. Apart from observations of rainfall and water supply (including water levels of dams and lakes), monitoring of soil moisture, food supply and food prices, especially in rural areas, could provide an early warning of approaching drought problems (Hughes et al., 1998).

4.4.3 Drought early warning system

Drought early warning in Malaysia is issued based on the criteria as provided in Table 4.1.

Table 4.1 Drought early warning criteria

MONITORING STATUS	LEVEL
LEVEL 1: ALERT	Deficit for total rainfall for at least 3 consecutive months above 35% from normal and the latest SPI index is less than -1.5, OR the deficit for 6 consecutive months above 35% and latest SPI index is less than -1.5.
LEVEL 2 : WARNING	Deficit for total rainfall for at least 3 and 6 consecutive months above 35% from normal and the latest 3 months SPI index is less than -1.5, and drought ALERT level has been declared.
LEVEL 3 : EMERGENCY	Deficit for total rainfall for at least 3 and 6 consecutive months above 35% from normal and the latest 3 months SPI index is less than -2.5, and drought WARNING level has been declared.
LEVEL 4 : TERMINATION	SPI index become positive and/or total rainfall for the current month above normal.

For effective drought risk management, a comprehensive and robust early warning system encompassing meteorological, hydrological and agricultural droughts must be established at national and local levels, with the support of communities. A comprehensive integration with common national standards of the meteorological and hydrological networks of DID and MMD needs to be undertaken to enable optimal use of resources. Maintenance issues must be addressed adequately to ensure timely availability and reliability of the observations.

The main constraints on the implementation of early warning information system are:

- Lack of a national drought policy framework;

- Limited coordination institutions that provide different types of drought early warning, risk management and risk reduction that results from a national policy;

- Inadequate social impact indicators to form part of a comprehensive early warning system and inform policy response (e.g., the social impacts of food shortages and higher food prices on poor people in both the rural and urban areas).

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) (2015a) has provided some guidance on early warning and monitoring strategies to its member states, which includes Malaysia:

- Strengthening seasonal forecasts for drought;

- Strengthening knowledge networks for transferring information and alerts from government agencies to farmers;

- Improved education of community and farmers; and

- Developing El Niño contingency plans by governments.

In addition, UNESCAP's Regional Drought Mechanism, launched in 2013, has provided an important platform for sharing free satellite-based data and products on drought monitoring and early warning system among drought-prone Asia-Pacific countries in a timely manner (UNESCAP, 2014). This platform, which complements WMO's Global Framework for Climate Services, provides more detailed and localised forecast and monitoring that can be updated during the growing season of crops (UNESCAP, 2015b).

4.4.4 Forest fires and haze monitoring

Monitoring of forest fires and haze, which calls for reasonably sophisticated technological know-how, is essential in order to mitigate their impacts. Monitoring techniques vary considerably among South East Asian countries. Malaysia's monitoring experience in the 1997/98 event was widely aerial surveillance for fire detection and monitoring. Hot spot information was received from the National Meteorological Services, among others.

The Department of Environment (DOE) operates an Air Pollution Monitoring System through Alam Sekitar Malaysia Sdn Bhd, where hourly reading of API for 52 monitoring sites throughout the country are published in the DOE's website. The monitoring system classifies an API reading of 0-50 as good, 51-100 as moderate, 101-200 as unhealthy, 201-300 as very unhealthy and values above 300 as hazardous (see Table 3.4 in Section 3.9). Forest fires are monitored and put under control by the respective state department of forest and the Fire and Rescue Services Department with the help of the Police. Not all districts have an air pollution monitoring system hence during haze emergency episodes decisions on actions in those districts without API readings have to be dependent on interpolated values which may not serve the purpose for early warning.

For transboundary haze, the MMD operates the HYSPLIT mode for prediction of the movement of the haze particles. The information on the places where hot spots are occurring in the region uses the NOAA satellite and haze map information provided by the ASEAN Specialised Meteorological Centre in Singapore as agreed by the ASEAN member countries. This information is further corroborated by satellite information from MMD and Malaysia Remote Sensing Agency.

After the 1997/98 El Niño event, ASEAN initiated a RHAP that established a monitoring and warning system for forest/vegetation fires, namely the SEA FDRS, adopted

from the Canadian Forest Fire Danger Rating System (http://haze.asean.org/fire-danger-rating-system-fdrs-for-southeast-asia-2/). The daily responsibility of producing the SEA FDR was handed over to the MMD by CFS in mid-September 2003. Since then, the MMD has been producing SEA FDR products on a daily basis to be used for predicting fire behaviour and for guiding policy makers in developing actions to protect life, property and the environment.

The meteorological variables used (temperature, relative humidity, rainfall and wind speed) are those measured at the meteorological stations throughout the region that are made available on the Global Telecommunication System (GTS). Spatial Analysis is carried out using the ArcView software.

4.4.5 Communication strategy

A comprehensive communication strategy, targeted at various vulnerable communities and groups, is needed to timely communicate early warning to all environmental, social and economic sectors, so as to reduce the impacts of El Niño and its prolonged drought, or the recurrent drought due to human-induced climate change.

The 11MP (Focus Area D, Strategy D1 "Strengthening Disaster Risk Management") provides for improvement in disaster detection and early warning capacity by upgrading detection technology and forecasting systems. Mapping of disaster prone and high risk areas is regarded as essential and it will enhance disaster detection efforts. Capabilities of all parties involved in disaster preparedness, response and recovery, including capacity to conduct forecasting analysis, will be strengthened to improve response time and effectiveness of disaster risk management. The following discussion will highlight the need to better integrate drought issues into policies and strategies. This must be construed to include wildfires induced by prolonged drought.

4.5 Drought coping mechanism

4.5.1 Existing policy and measures

There is no existing policy specific for drought. In Malaysia, the management of disasters is guided by the National Security Council (NSC) Directive No. 20: The Policy and Mechanism for National Disaster Management and Relief. This Directive covers all disasters, including drought, which is regarded as a "natural disaster", even though drought can also be human-induced because of human-induced climate change.

4.5.2 Improve drought coordination mechanism

The National Security Council (NSC) Directive No. 20: The Policy and Mechanism for National Disaster Management and Relief is an executive directive of the Prime Minister enforced since 11 May 1997 and updated on 30 March 2012.

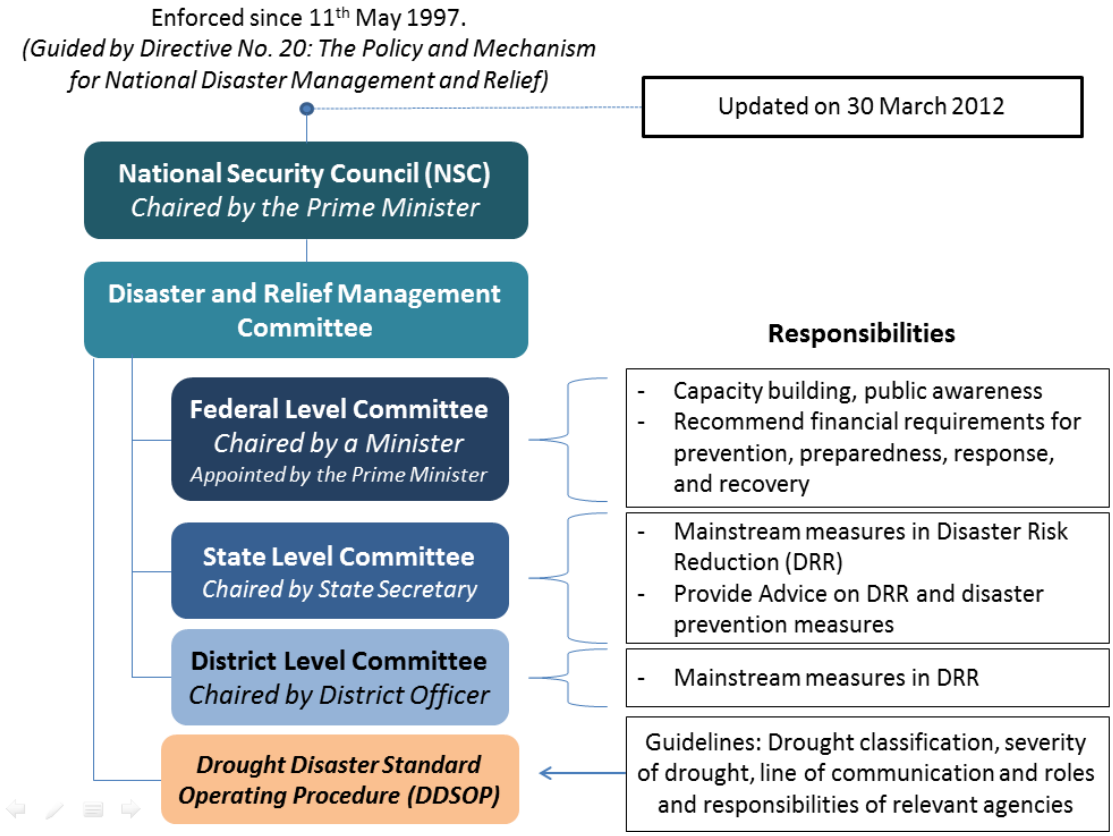


Figure 4.3 The policy and mechanism for national disaster management and relief

As illustrated in Figure 4.3, the Directive prescribes three levels of disaster management mechanism (Federal, State and District) depending on the severity of the disaster. This is achieved through the establishment of the Disaster and Relief Management Committee at the three respective levels, with the NSC at the respective level acting as the secretariat to the committee. At the Federal level, the Committee is chaired by a Minister appointed by the Hon. Prime Minister; and at the State level it is chaired by the State Secretary. At the District level, the District Officer chairs the district level committee. The scope of work and responsibilities of the NSC and the three level committees are prescribed in the directive. For the committee at the Federal level, capacity-building, public awareness and recommendation of financial requirements for prevention, preparedness, response and recovery are also among the scope of work listed for the committee. For the committee at the state and district levels, mainstreaming measures in disaster risk reduction effectively through the government agencies at the state and district levels has been listed in the committees' scopes of work. The responsibility of the Chairman of the State Disaster Management Committee to the Chairman of the Working Committee on State Security includes provision of advice on measures on disaster risk reduction, including disaster prevention.

For the management of drought disasters, the directive is supported by the Drought Disaster Standard Operating Procedure (DDSOP) which was formulated by all the relevant agencies and overseen by the NSC of the Prime Minister's Department. The DDSOP was formulated following several drought events that had occurred in Malaysia, particularly the ones in 1992 and 1998, and it was first circulated in December 2011. The DDSOP provides guidelines on matters related to classification of droughts, the responsible agencies for monitoring drought, severity of drought, line of communication and roles and

responsibilities of relevant agencies should the drought event be classified to have reached dangerous level.

Regarding El Niño, currently MMD monitors its occurrence and development, informs relevant government departments, and provides regular updates.

Inter-agency coordination and collaboration in preventing and mitigating drought, including monitoring, has always been a challenge especially where some responsibilities are overlapped.

4.5.3 National Drought Committee

When drought occurs, haze is often a major issue. A National Haze Committee chaired by the NRE was established in 1996 with the participation of National Security Council, Forestry Department (Peninsular Malaysia), Malaysian Meteorological Department, Department of Agriculture, Ministry of Health, Ministry of Education, and Fire and Rescue Department, to decide on the actions to be undertaken to reduce the adverse effects of haze when it happens during the drought period.

The Task Force of this report proposes to establish a National Drought Committee in parallel to the National Haze and Hot Weather Main Committee, with the participation of the same ministries and departments, as shown in Figure 4.4. Perhaps the Ministry of Industry may be included. The National Drought Committee is to coordinate all activities relating to drought risk reduction, from monitoring, early warning to drought prevention, preparedness, recovery and assessment of environmental, social and economic impacts. Its role and activities are to complement the National Haze and Hot Weather Main Committee. It is important to bring out the synergies between the proposed National Drought Committee and the current National Haze and Hot Weather Main Committee.

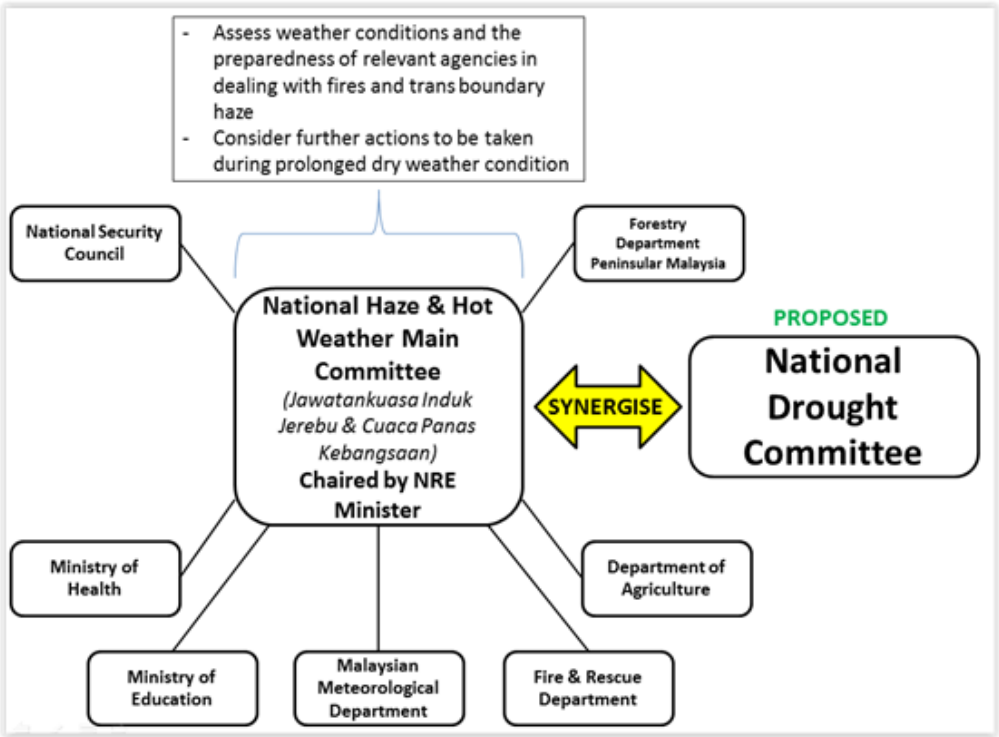


Figure 4.4 Proposed establishment of a National Drought Committee

4.5.4 Public participation

So often the general public and communities are left out in the national coordination mechanism for combating drought, forest fires and haze. An effective national coordination mechanism must include the active participation of the local communities, which are most vulnerable to the impacts of El Niño. A strategy to mobilise the participation of local communities should be developed at the district level. This strategy may be developed as an integral part of climate change adaptation strategies.

4.6 Mitigating the adverse effects of drought

4.6.1 Technical and technological measures

There are technical and technological measures for drought risk reduction and for mitigating the adverse effects of drought (Ahmad and Low, 2003; UNISDR, 2003, 2007), including the following:

(A) Adaptation to increase resilience

This is definitely a critical part of the solution to the El Niño events in order to minimise the impacts of increasingly frequent and severe extreme weather events. Over time in Malaysia, innovative and adaptive ways to cope with prolonged dry periods have taken the form of dams, huge lake reservoirs and systematic irrigations. How will new technology and innovation play a role in mitigating and adapting to more intense drought as a recurring hazard in a changing climate?

(B) Integrated Drought Management (IDM)

This approach cuts across sectors, disciplines, and institutional jurisdictions. WMO and the Global Water Partnership have launched the Integrated Drought Management Programme in 2015. Under this initiative, WMO set up a HelpDesk on Drought Management and launched various projects at the regional level through the network of the Global Water Partnership. (See: http://public.wmo.int/en/media/news/wmo-highlights-integrated-drought-man

(C) Integrated Water Resources Management (IWRM)

This is another option to reduce the occurrences of water shortage especially during drought. It aims to integrate management of water resources at the basin or watershed scale, integrating both supply-side and demand-side approaches and infrastructure system improvements to overcome the problems of water shortages during the period of drought. The technology identified as having great potential impact on the water sector relates to efficient water use and distribution, to water pollution, and to the selection of drought-, pest- and salt-resistant crops that are expected to reduce water usage and, subsequently, enhance water availability. This will include water reuse and water-recycling technology and the use of renewable energy in the water sector. Some examples of IWRM in the agricultural sector have been discussed by Tawang et al. (2002) and Tawang and Tengku Ahmad (2003) as provided in Section 3.3.4.

There is a need to assess existing water resources (including groundwater and its quality) and the consumption patterns in Malaysia, and estimate the future availability and consumption trends in the next 10, 20, 30 and 50 years based on the climate change scenarios. In addition, it is important to develop an IWRM plan for the region, including drought adaptation and coping mechanisms.

IWRM and IDM are complementary to each other.

There are a number of potential areas for cooperation across government agencies, statutory bodies, private sector and communities, as highlighted by Low (2014):

(i) Manage water resources in an integrated manner;

(ii) Minimise wastage by effectively managing demand;

(iii) Reduce contamination by minimising preventable water pollution;

(iv) Diversify sources of water;

(v) Invest in Research & Development (R&D) in developing technologies that can reduce the cost of supplying water.

New technology and research play an important role in strengthening good practices to alleviate drought impacts to improve reliability and affordability.

(D) Cloud seeding

The main effort in times of drought is to create rain on water catchment areas. The MMD undertakes cloud seeding activities and make decisions on the suitability of the operation, taking into consideration the presence of suitable rain clouds, high humidity, and unstable weather conditions. However, the scientific understanding, technology and success rates of cloud seeding are low. Enhanced scientific knowledge in weather modifications and better technology are needed to enable the MMD to coordinate more effective cloud seeding operations with other agencies, such as the National Security Council, Royal Malaysian Air Force, DOE and State Water Board.

(E) Pahang-Selangor Raw Water Transfer Project

Another mitigation measure put in place by the Government is the interstate raw water transfer project, a technological solution to transfer raw water from the Semantan River in Pahang to the Hulu Langat Water Treatment Plant (WTP) in Selangor and to be distributed to meet the water demands in Selangor and Federal Territory (Kuala Lumpur and Putrajaya). The project, which is under the auspices of KeTTHA, involves construction of three 44.6km-long tunnels, the longest tunnel in South-East Asia. The project, expected to complete by 2019, will have the capacity to channel 1.89 billion litres of water a day from Pahang to Selangor. The WTP will have a capacity of 1,200 million litres per day[18].

However, the sustainability of water resources from Semantan River remains a great challenge in the future.

(F) Water conservation

Just like energy conservation is an important measure to save energy, water conservation is also an important measure to reduce the consumption of water, especially during the drought period. With daily water consumption of about 230 litres per person per day, Malaysia's average water consumption is much higher than that of Singapore at 150 litres per person per day and of Thailand at 180 litres per person per day (Air Selangor, 2015). Raising public awareness on water conservation and minimising the loss of non-revenue water should be an integral part of sustainable water resources management.

[18]http://www.water-technology.net/projects/pahang-selangor-raw-water-transfer-tunnel-project/

(G) Rainwater harvesting

In the Pacific small island states, such as Tuvalu where fresh water resources are limited, rainwater harvesting is a common practice for every household. However, rainwater harvesting is not widely practised in Malaysia, especially at the household level. The Government has introduced a set of guidelines in 1999 to encourage rainwater harvesting, so that the rainwater collected can be used for domestic purposes (Raj, 2007).

The potential for rainwater harvesting during rainy season is enormous. It is important to raise public awareness on the significance of rainwater harvesting, which only involves simple technology. The literature on rainwater harvesting is abundant.

The investment for a simple household rainwater harvesting system is modest. The costs cover water storage tanks, the gutters and pipes that direct rainwater from the roof catchment to the storage tanks, and the cost of installation. Rainwater harvesting may also be designed for larger industrial and commercial buildings.

It would be useful to undertake an assessment of ways and means to enhance rainwater harvesting in drought prone areas, including the feasibility for establishment of groundwater recharge systems.

4.6.2 Policy measures

An effective policy will ensure an effective strategy, which, in turn, will ensure an effective strategic plan to address all scientific, technical, technological, as well as social and economic issues related to drought.

Policy measures could include both legal (e.g., laws and legislations) and economic instruments (e.g., tax; water charge; subsidy; fines; incentives or disincentives) for water consumption and water conservation.

Other policy measures could include planning and zoning, which are also for drought risk reduction, especially in drought prone areas. Raj (2007) highlighted the importance of basin-wide planning for water resource augmentation, which has implications for both flood and drought risks reduction. Basin-wide planning requires extensive knowledge of water users and their consumption patterns; water diversions and storage; and management practices in all parts of the basin, as well as the past, present, and projected future meteorological and hydrological conditions (Raj, 2007).

Raj (2007) also highlighted the importance of inter-agency collaboration, in view of the fact that reservoirs for irrigation, water supply and flood mitigation have conflicting operational rules.

It may be necessary to amend existing environmental legislations and water laws to enable effective drought risk reduction to be implemented throughout Malaysia. In particular, Raj (2007) pointed out that under the Federal Constitution, the State Governments have jurisdiction on matters pertaining to water, rivers, land, and forest, and hence they are responsible for managing any disasters and risks related to these sectors. Thus, it may be necessary to amend the Federal Constitution, so that the various state jurisdictions can be implemented in a more coordinated and consistent manner, even though politically it may not be easy to achieve due to competing state interests. Within this context, inter-state collaboration is also important in terms of strengthening drought risk reduction throughout Malaysia.

4.7 Public Awareness

Article 6 of the United Nations Framework Convention on Climate Change (UNFCCC) emphasises the importance of education and public awareness in addressing climate change, of which drought will be a permanent feature. Indeed, enhancement of public awareness on drought risk reduction may be undertaken as an integral part of any climate change awareness programmes, though the focus should be specific to drought.

Public awareness programmes on drought risk reduction may be undertaken via mass media (e.g., newspapers, radio, TV, brochures; relevant government websites, etc.). They could cover the scientific, technical and technological, as well as social and economic issues related to El Niño and drought risk reduction in various social and economic sectors. In particular, good local and community practices, including indigenous knowledge, that reduce the vulnerability of populations in drought-prone areas, should be widely disseminated.

The civil societies and non-governmental organisations, which are working closely with local communities, can play an important role in raising the awareness of the local communities on El Niño and drought risk reduction.

Relevant websites of the Government are useful information sources for enhancing public awareness. For example, MMD[19] provides forecasting on the development of El Niño within certain limit of uncertainty. DOE has set up the website http://apims.doe.gov.my/v2/advice.html to disseminate haze-related information, for queries and to warn the public against certain activities, such as under certain meteorological conditions, open burning is prohibited as it may worsen the haze situation.

The 11MP provides for comprehensive communication and awareness programmes to coordinate and integrate public awareness messages communicated by different public sector agencies and on different themes, including climate change and disaster risk management. In addition, there are synergies between the three Rio Conventions, namely UNFCCC, Convention on Biological Diversity (CBD), and the United Nations Convention to Combat Desertification (UNCCD), on addressing drought. These synergies should be encouraged in the public awareness programmes developed under the implementation of these three Conventions by the Government.

4.8 Capacity development

Malaysia's adaptive capacity to deal with El Niño, especially in the agricultural sector, has been weak (Abul Quasem Al-Amin and Gazi Mahabubul Alam, 2016). It is clear that much human and institutional capacity development is needed across all socio-economic sectors, not only at the scientific, technical and technological levels, but also at the policy levels (i.e., among policy and decision makers).

The scientific and technical capacity of the local community, especially rural communities, may also be enhanced through a properly designed training and public awareness programmes.

Capacity development for drought risk reduction can be coordinated, implemented and monitored under a holistic and integrated coordination mechanism, such as the proposed National Drought Committee (see Section 4.5.2).

Sub-regional collaboration within the framework of ASEAN could facilitate capacity development on drought risk reduction among ASEAN members. To this end, a South-East Asia Network for Drought Risk Reduction (SEANDRR) may be established under the auspices of the ASEAN Secretariat to facilitate sub-regional collaboration for drought risk reduction,

[19] http://www.met.gov.my/

especially capacity development activities, so as to build resilience for drought risk reduction within the ASEAN members (see Section 4.13).

In addition, international and regional cooperation, including UNESCAP's Regional Drought Mechanism, and South-South Cooperation, can also play an important role in capacity development activities. These include collaboration in scientific, technical and technological research, Visiting Fellowships programme, and scientists exchange programme, joint publications, among others.

Under the UNFCCC, there are capacity-building activities on adaptation to drought. Similarly, under the UNCCD, there are also capacity-building on mitigating the adverse effects of drought. Malaysia, as a Party to the above conventions, may make use of the opportunities for capacity-building activities offered by these two conventions.

4.9 Economics of drought

It is clear that the 1997/98 El Niño-induced drought has caused negative impacts on various socio-economic sectors in Malaysia. However, drought, as well as forest/peatland fires and associated haze, also occurred during non-El Niño years. Thus, Malaysia must develop a comprehensive and an integrated framework (see Section 4.10) and strategy guided by effective policy (see Section 4.11) so as to better cope with drought, forest/peatland fires and associated haze.

In order to provide decision makers with an important tool for making decision, it is imperative for the scientific community (including social scientists and economists) in Malaysia to undertake a comprehensive assessment on the economics of drought. This assessment would include direct and indirect costs, economy-wide costs, the valuation of biodiversity and ecosystem services, and the cost of contribution to climate change. In particular, the cost of prevention versus mitigation, and the cost of action versus inaction.

In view of the interactions of drought with climate change, biodiversity and land degradation, the economics of drought can be an integral part of the economics of climate change, biodiversity and land degradation, which, in turn, are integral parts of the economics of sustainable development. There are synergies between climate change, biodiversity and land degradation.

Much research is needed in the above-mentioned areas.

4.10 A framework for drought risk reduction

In many developing countries, drought management practices are largely based on crisis management, implying that practices are reactive rather than proactive, and therefore, they do not address the underlying causes for vulnerabilities and hence the risks associated with drought.

Globally, disaster risk governance mechanisms have been considered effective in regulating disaster risk at international and national levels over the last two decades. For instance, the Hyogo Framework for Action (HFA) for Disaster Risk Reduction (DRR) 2005-2015, which embraces the vision of building countries' and communities' resilience to disasters, has encouraged countries in the developing world to gradually shift from reactive to anticipatory disaster risk management. The HFA effectively provides the international foundation for reducing disaster risks, as agreed by Governments at the World Conference on Disaster Reduction in January 2005. The Sendai Framework for Disaster Risk Reduction 2015-2030 – the successor of the HFA – is built on the facts that continuity in risk reduction cannot be adequately implemented by the member states alone, because other stakeholders such as academia, civil societies and private sectors are needed to play active roles. The

framework was adopted by member states at the Third UN World Conference on DRR in Sendai, Japan, on 18 March 2015.

Some major initiatives toward implementing the priority areas of the HFA have been taken in Malaysia as evidenced by the development of National Action Plan for Disaster Risk Reduction (Pereira et al, 2014). In terms of drought, the process of drought risk reduction and its mainstreaming into national development frameworks should be participatory, involving a wide range of stakeholders such as national and local governments, community-based and civil society organisations, regional and sub-regional organisations, multilateral and bilateral international bodies, the scientific community, the private sector and the media.

The United Nations International Strategy for Disaster Reduction (UNISDR) proposes a framework that contributes to the priorities of the HFA (UNISDR, 2007). This global framework contains five elements, as follows:

- Element 1: Policy and governance
- Element 2: Drought risk identification, risk monitoring and early warning
- Element 3: Drought awareness, knowledge management and education
- Element 4: Reducing underlying factors of drought risk
- Element 5: Enhancing mitigation measures and preparedness for drought

Guiding principles are provided for each of the above elements.

This framework, which is attached in Appendice 2, may be used as a good reference for guiding the development of a national framework for drought risk reduction within the context of Malaysia, based on national circumstances, including national, state and local needs and division of responsibilities, community participation, networks and coordination mechanisms at all levels and resource availability, taking into account potential synergies in terms of institutional and implementation capacities among government agencies and other stakeholders.

4.11 Drought, climate change and sustainable development

4.11.1 National climate change policy

Malaysia has a National Policy on Climate Change that "provides the framework to mobilise and guide government agencies, industry, community as well as other stakeholders and major groups in addressing the challenges of climate change in a holistic manner". "Emphasis is on strengthening capacity of the nation to reduce the country's vulnerability to climate change whilst promoting mitigation response that also enhances sustainable development" (MONRE, 2009).

The objectives of the National Policy on Climate Change are:

(a) "Mainstreaming climate change through wise management of resources and enhanced environmental conservation resulting in strengthened economic competitiveness and improved quality of life."

(b) "Integration of responses into national policies plans and programmes to strengthen the resilience of development from arising and potential impacts of climate change."

(c) "Strengthening of institutional and implementation capacity to better harness opportunities to reduce negative impacts of climate change."

Although "drought" has not been specifically mentioned in the National Policy, one of the key actions (KA) in the National Policy (i.e., KA28-ST7) is to "establish and implement a national R&D agenda on climate change taking into account the following areas: Agriculture and food security; water security and services; forestry and ecosystem services; public health services and delivery; localised modelling for projection of future scenarios; vulnerability due to extreme weather events and natural disasters", among others.

KA27-ST6 "Enhance the coordinating mechanism to oversee the planning, implementation and monitoring of climate change measures".

KA33-ST7: "Institutionalise measures to strengthen effective linking climate science and policy".

KA36-ST8: "Promote community-based climate change responses and programmes".

As drought will be a frequent natural or human-induced hazard in a changing climate, it should be an integral part of the effective climate change strategy and policy that are essential to guide national sustainable development.

4.11.2 National sustainable development policy

Sustainable development promotes environmental, social and economic sustainability (Brundtland, 1987; United Nations, 2012), which are inclusive and mutually supportive, and which should not be "balanced" among each other but to be "integrated" into one entity. So often environmental protection is sacrificed at the mercy of economic development, and it has become an afterthought rather than an element that should be considered right from the beginning on the drawing board. Thus, there is a need for paradigm shift for achieving. However, sustainable development can only be achieved with effective policy, political commitment and good governance.

Following the mainstream in the world guided by the United Nations (UN), Malaysia has been an active participant in all conferences related to sustainable development organised by the United Nations since the UN Conference on Environment and Development (UNCED) or Earth Summit at Rio de Janeiro held in 1992. Malaysia has a local Agenda 21: A global action plan for sustainable development. Malaysia is a Party to the three Rio Conventions - UNFCCC, CBD, and the United Nations Convention to Combat Desertification (UNCCD), all of which aim to achieve sustainable development. In September 2000, Malaysia was a Party that adopted the Millennium Development Goals. On 25 September 2015, the UN General Assembly (including Malaysia) adopted the SDGs (United Nations, 2015)[20]

The 11MP has also included Green Growth, which promotes environmental sustainability by efficient use of natural resources and minimisation of adverse environmental impacts (Ekins, 2000; UNESCAP, 2013), as an important agenda for sustainable development.

Several policies in Malaysia have been developed to advance the sustainable development and green growth agenda.

(a) National Policy on Climate Change 2009: To mainstream climate changes through wise management of resources and enhanced environmental conservation resulting in strengthen economic competitiveness and improved quality of life.

(b) National (Second) Physical Plan 2010: Spatial planning that guides the direction and pattern of development, use and maintenance of the strategic land (15-20 years).

[20]http://www.un.org/sustainabledevelopment/sustainable-development-goals/

(c) National Urbanisation Plan 2006: Comprises 30 specific policies to be referred in order to plan, develop and manage the urban environment.

(d) National Green Technology Policy 2009: Toward a low carbon economy through the usage of green technology as a solution for global warming (Rosly, 2011)

The 11MP informs that national sustainable development will be achieved in a resilient, low-carbon, resource-efficient, and socially-inclusive manner.

However, all policies, no matter how good they are, must be efficiently and effectively implemented. Otherwise they remain useless.

4.11.3 Mainstreaming drought risk reduction into climate change and sustainable development policies

As drought is expected to be a more frequent event in the changing climate, thus it should be an integral component of the national climate change policy and strategies, which, in turn, should be an integral component of national sustainable development policies and strategies, as illustrated in Figure 4.5.

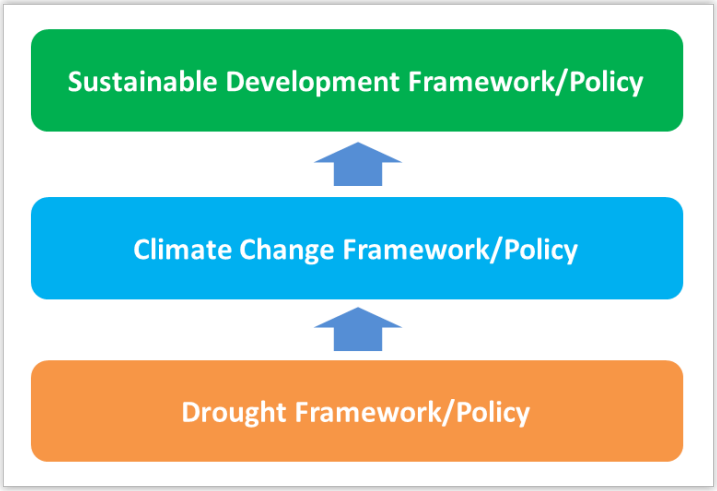


Figure 4.5 Mainstreaming drought risk reduction into climate change and sustainable development policies

However, mainstreaming drought risk reduction into national climate change and sustainable development policy frameworks will require a holistic approach, comprehensive scientific and policy research, strong institutions, good inter-agencies coordination, extensive and inclusive stakeholders (including communities) participation, as well as political commitment at all levels for effective implementation, and appropriate governance.

4.12 Towards a new policy for drought risk reduction

The slow onset and the non-structural damage caused by drought seem to have attracted less attention by policy makers compared to the more rapid onset hazards usually characterised by massive structural losses such as flood.

Ahmad and Low (2003) advocated the need for a drought policy and management strategies in Malaysia after the prolonged drought induced by the 1997/98 El Niño event. They commented then that "Drought management in Malaysia currently has been reactive, relying largely on crisis management. This approach has its weaknesses such as untimely response, poor coordination, and poorly targeted to drought stricken groups or areas."

However, almost 20 years after the 1997/98 El Niño event, the focus in Malaysia seems to be still on drought management rather than drought risk reduction. The approach for drought management remains largely the same: reactive rather than proactive.

Wilhite et al. (2014) also highlighted the importance of adoption of national drought policies that are focused on risk reduction and complemented by drought mitigation or preparedness plans at various levels of government, so as to improve the coping capacity of nations to manage drought events in association with a changing climate.

Thus, a fundamental shift in focus and approach is needed if an integrated policy for drought risk reduction is to be formulated in Malaysia, taking into account the projected more frequent and/or intense drought events caused by human-induced climate change.

The 11MP 2016-2020 seeks to drive disaster risk management and climate change resilience. However, instead of managing drought risks, the new national drought policy must seek to reducing drought risks.

A new policy for drought risk reduction must include the economics of drought. Indeed, ineffective policies for addressing drought could have significant implications for environmental, social and economic impacts and consequences. Thus, the costs of ineffective policies should be considered and included in the analysis on the economics of drought.

4.13 South-East Asia Network for Drought Risk Reduction (SEANDRR)

It is more cost-effective to improve drought coping and adaptation capacity through a regional partnership. Thus, it is proposed to establish a SEANDRR to facilitate sub-regional collaboration for drought risk reduction, especially capacity development activities, so as to build resilience for drought risk reduction within the ASEAN members.

This Network will complement and strengthen national capacity development programmes to enhance human and institutional capacities to better cope with future drought events. It will be an important platform for providing and sharing information, data, expertise, good practices and lessons learned on all scientific, technical, technological and policy aspects related to drought risk reduction.

Malaysia may take the lead to initiate the establishment of this network under the auspices of the ASEAN Secretariat.

Chapter 5: Conclusions and Policy Recommendations

5.1 Conclusions

Based on the information and analyses provided in Chapters 2, 3 and 4, a number of conclusions can be drawn, as follows:

(1) El Niño is a natural phenomenon that has profound impacts around the world. It typically brings drought condition in the western Pacific region, including Malaysia. Drought is the world's most destructive natural or human-induced hazard.

(2) In the past three decades, tremendous progress has been made in scientific understanding of ENSO system, both in theoretical and observational aspects. The setting up of the TAO Arrays in 1994 made the monitoring of the state of ENSO system possible in almost real time.

(3) The recent initiative to develop an El Nino Action Plan that is based on a rainfall depletion indicator would ensure better uniformity, coordination and implementation of efforts to reduce the negative impacts of El Nino, which induces prolonged drought and the outbreak of forest fires and associated haze.

(4) As evidenced by the 1997/98 El Niño event, which was one of the strongest El Niño events on record, the impacts of El Niño on the environmental, social and economic sectors are profound. Significant reduction in rainfall had greatly affected water supply, which, in turn, had resulted in the loss of agricultural (e.g. oil palm, paddy and cocoa) and industrial productivity, as well as reduced hydro-electricity production. In addition, prolonged drought affected terrestrial ecosystems, while the warmer ocean temperature affected marine ecosystems and caused extensive coral bleaching, affected fisheries with reduced fishes landing. Forest fires destroyed forests, animal habitats, biodiversity (including endangered species, such as orangutan), while the greenhouse gas emissions from the forest fires have significant implications for climate change. The transboundary haze generated by the forest fires seriously affected health, and disrupted tourism and education, among others.

(5) It was estimated that the economic losses in Malaysia associated with the haze episode during August-October 1997 was RM801.9 million (or US$321 million at 1997 exchange rate), mainly contributed by the loss in productivity during the state of emergency in Sarawak from 19 to 28 September, RM393.51 million (USS$157.4), which accounted for 49.07% of the total; followed by decline in tourists arrival, RM318.55 million (US$127.42), or 39.72% of the total. Other losses included decline in fish landing (RM40.58 million (US$16.23 million) or 5.00%; cost of fire-fighting RM 25 million (US$ 10 million) or 3.12%; adjusted cost of illness RM21.02 million (US$8.41 million) or 2.62%; cloud seeding, RM2.08 million (US$0.83 million) or 0.26%; expenditure on masks, RM0.71 million (US$0.28 million) or 0.09%; and cancellation of flights, RM0.45 million (US$0.18 million) or 0.06%, respectively. However, the above estimate was very conservative as it did not account for the economy-wide costs, as well as the loss of biodiversity and ecosystem services. With new data and new methodologies, an assessment of the total cost over the whole period of the 1997/98 El Niño event would be very useful.

(6) Although El-Niño-induced drought could not be prevented, but its impacts, such as forest fires and associated haze, could be prevented. Scientific (e.g., monitoring and early warning), technical (e.g., integrated drought management; integrated water resources management) and technological measures (e.g., water conservation, rain harvesting) are available to reduce the impacts of drought. Effective policy measures,

including an effective national drought risk reduction coordination mechanism, are essential for coping with prolonged drought.

(7) To reduce the risk for drought exposure, it is important to identify and minimise the factors (e.g., prevention, preparedness, mitigation, environmental, social, economic, technical, technological, financial, human capacity and policy, among others) that may reduce the vulnerability of a country to drought. Poverty could be an important factor that makes the poor people more vulnerable to drought.

(8) El-Niño events are caused by natural climate variability. However, the frequency, magnitude, intensity and duration of El Niño may be exacerbated by human-induced climate change. Thus, drought risk reduction is an integral part of climate change adaptation to drought, and drought risk reduction framework and policy should also be an integral part of climate change framework and policy, which, in turn, should be an integral part of sustainable development framework and policy.

(9) Although lessons may be learned from the past El Nino events, it may be noted that, as pointed out by Hughes et al. (1998), no two ENSO events are the same or even closely similar in their global characteristics or effects, let alone at the regional or national level.

5.2 Policy Recommendations

A number of policy recommendations are provided for policy makers, as follows:

(1) Any actions to address the impacts of El Niño events and limit their impacts must be science-based. These include assessment on the need for more coordinated action for monitoring and early warning systems that deliver timely information to decision-makers and the general public and communities; improved impact assessment procedures; risk management measures and preparedness plans; and stronger emergency response programmes.

(2) There is a need to monitor El Niño using forecast products from established forecast centres. There is also a need to monitor other climate phenomena such as the IOD and MJO.

(3) There is a need for a holistic and proactive approach in addressing the impacts of El Niño. In order to strengthen the national coordination mechanism for drought risk reduction, a National Drought Committee may be established based on the model of National Haze and Hot Weather Main Committee, with a view to coordinating all issues relating to drought risk reduction, including prevention and mitigation measures.

(4) Malaysia must develop effective policies that engender cooperation and coordination at all levels of authority to increase their capacity to cope with extended periods of water scarcity in case of a drought. The ultimate goal of these efforts is to create societies that are more resilient to drought.

(5) There is a need to strengthen scientific, technical and technological research, including research on local and regional climate variability and build Malaysia's own seasonal forecasting system.

(6) The occurrences of El Niño and La Niña have caused changes to the annual historical rainfall pattern. Rainfall records are the basis of "hydrological procedures" used for designing hydraulic structures and systems like dams and irrigation system. Therefore, there is a need to review these hydrological procedures to ensure accurate design and operation & maintenance of the structures and systems.

(7) There is a need to develop a long-term policy for drought risk reduction – preventive, proactive and risk-based, rather than reactive and 'crisis-based'; and to mainstream drought risk reduction into climate change and sustainable development frameworks and policies.

(8) It is important to map the variations in vulnerabilities and impacts (environmental, social and economic) across various sectors and geographical locations in the country. Based on past El Niño events, which may be classified as weak, moderate and strong events, these variations could be analysed and studied and taken into account in dealing with the impacts of future El Niño events.

(9) There is a need to strengthen social and economic research on the impacts of El Niño, including the economics of drought (e.g., the valuation of biodiversity and ecosystem services; the cost of prevention versus mitigation; the cost of action versus inaction), so as to provide the policy and decision makes with a good basis for making informed decisions.

(10) Further strengthening of human and institutional capacity at the national, state and locals is needed for drought risk reduction, which is multi-disciplinary. Malaysia's higher education system has an important role to play in capacity development.

(11) Malaysia may take the lead to initiate the establishment of a SEANDRR perhaps under the auspices of the ASEAN Secretariat. This sub-regional Network will facilitate capacity development by bringing together people and institutions within the ASEAN members with the goal of increasing interactions and linkages for sharing regional and national policies and strategies to improve drought preparedness and management, and mitigate the effects of drought. It will share data and information relating to drought, including case studies on good practices and lessons learned. It will complement and strengthen national capacity development programmes to enhance human and institutional capacities to better cope with future episodes of drought.

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Appendices

Appendix 1: List of ministries and experts contacted for the First Task Force meeting held on 18 September 2014. Those highlighted in yellow attended the meeting.

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Appendix 2. Drought Risk Reduction Framework

Element 1: Policy and governance

Based on local needs, community participation and political commitment, networks and mechanisms and resource availability. In addition to national and state/provincial drought policies, increased importance has also been placed on local/community level drought policy and planning, emphasizing self-reliance and drought resilience.

The development of national and local strategies for reducing drought risk, together with the implementation of such a strategy, should be guided by the following principles:

1. Political commitment, high-level engagement, strong institutional setting, clear responsibilities both at central and local levels and appropriate governance are essential for integrating drought risk issues into a sustainable development and disaster risk reduction process.
2. A bottom-up approach with effective decentralization and active community participation for drought risk management in planning, decision making and implementation, is essential to move from policy to practice.
3. Capacity building and knowledge development are usually required to help build political commitment, competent institutions and an informed constituency.
4. Drought risk reduction policies should establish a clear set of principles or operating guidelines to govern the management of drought and its impacts, including the development of a preparedness plan that lays out a strategy to achieve these objectives.
5. Drought-related policies and plans should emphasize risk reduction (prevention, mitigation and preparedness) rather than relying solely on drought (often turned into famine) relief;
6. Drought monitoring, risk assessment and other appropriate risk reduction measures are principal components of drought policies and plans.
7. Institutional mechanisms (policy, legislative and organizational) should be developed and enforced to ensure that drought risk reduction strategies are carried out.
8. Sound development of long-term investment in risk reduction measures (prevention, mitigation and preparedness) is essential to reduce the effects of drought.

Element 2: Drought risk identification, risk monitoring and early warning

A starting point for promoting a culture of resilience in combination with enhancing knowledge about hazard occurrence, the potential effects of the hazard, and the related vulnerabilities of potentially affected people and activities. Risk assessment methodologies such as hazard assessment, drought impact assessment and vulnerability analysis will be useful in order to better understand specific trends, vulnerability and impacts of drought for specific drought prone areas. It is recommended that common methodologies for defining and assessing risks as well as appropriate drought hazard and vulnerability indicators be developed to meet specific local needs. Enhancing drought monitoring and early warning capacities is also crucial.

Drought risk identification, impact assessment, and early warning activities should be guided by the following principles:

1. Drought risk is the combination of the natural hazard and the human, social, economic and environmental vulnerability of a community or country, and managing risk requires understanding these two components and related factors in space and time.
2. Increasing individual, community, institutional and national capacities is essential to reducing vulnerability to drought impact.
3. Impact assessment plays an important role in drought risk management, in particular, identifying most vulnerable groups and sectors during drought.
4. Drought monitoring and early warning systems play an important role in risk identification, assessment and management.
5. Changing climate and the associated changing nature of drought poses a serious risk to the environment, hence to sustainable development and the society.

Element 3: Drought awareness, knowledge management and education
Another enabling factor for drought risk reduction. Collection, compilation, and dissemination of relevant knowledge and information on hazards, vulnerabilities, and capacities should be linked to community drought risk reduction awareness campaigns, programmes, and projects. Interaction between the generators and users of information is essential for developing useful messages and helping to ensure the use of the information. Education for disaster risk reduction is an interactive process of mutual learning among people and institutions which also involves traditional wisdom and local knowledge. Various educational programmes that focus on drought risk reduction exist in addition to general programmes on DRR.

In general, drought awareness and knowledge management activities should be guided by the following principles:
1. The effects of drought can be substantially reduced if people are well informed and motivated toward a culture of disaster prevention and resilience.
2. Effective information management and exchange requires strengthening dialogue and networks among disaster researchers, practitioners, and stakeholders in order to foster consistent knowledge collection and meaningful message dissemination.
3. Public awareness programmes should be designed and implemented with a clear understanding of local perspectives and needs, and promote engagement of the media to stimulate a culture of disaster resilience, including resilience to drought and strong community involvement.
4. Education and training are essential for all people in order to reduce local drought risk.

Element 4: Reducing underlying factors of drought risk
Will also contribute to reducing drought vulnerability. These risk factors can be reviewed and reduced by effective environmental and natural resource management, social and economic development practices, and land-use planning and other technical measures. These factors that have an impact on vulnerability to drought need to be reflected in national poverty reduction strategies, development plans, sector development planning and programmes, and environment and natural resource management strategies as well as in post-disaster situations so that effective preparedness and mitigation measures can be considered.

The guiding principles are:
1. Mechanisms should be in place to systematically bring together practitioners in disaster risk reduction (e.g., national platform members) and key institutions involved in environmental management (e.g., adaptation to climate change, desertification and biodiversity).
2. Areas of overlap and synergy should be identified between existing environmental programmes and disaster risk reduction activities.
3. A mechanism for carrying out joint assessments should be institutionalised to integrate disaster risk reduction and environmental protection parameters (e.g., integrated risk-and-environmental-impact assessments).
4. Specific attention should be given to socio-economic high-risk factors such as age, disabilities, social disparities and gender. By focusing on protection of the most vulnerable groups, the impacts of disasters can be reduced.
5. Post-drought recovery planning can incorporate drought risk reduction strategies for the future.
6. Safety nets such as insurance mechanisms for properties as well as microcredit and financing for ensuring minimum livelihood means can accelerate post-drought recovery process.

Element 5: Enhancing mitigation measures and preparedness for drought
Substantially reduce drought impacts and losses if authorities, individuals, and communities are well-prepared, ready to act, and equipped with the knowledge and capacities for effective drought management. It should be recognized that mitigation and preparedness have a greater impact on reducing the scale and effects of drought disasters than ad-hoc emergency response measures.

The guiding principles are:
1. Prevention, mitigation and preparedness are central components of disaster risk reduction, and are more important than relying solely on ad-hoc emergency response measures.
2. Dialogue, exchange of information, and coordination are needed between disaster risk reduction, development and emergency management actors.
3. The selection of appropriate drought risk reduction (prevention, mitigation and preparedness) measures requires many considerations, such as integrated environmental and natural resource management, social and economic development, land use planning opportunities, and climate change adaptations.
4. A combination of top-down and bottom-up approaches is required for development and implementation of effective mitigation and preparedness measures.
5. Institutional capacity, coordinated mechanisms, identification of local needs and indigenous knowledge are required to implement effective mitigation and preparedness strategies.
6. Monitoring and early warning are key elements of disaster risk reduction and must be closely linked to other risk reduction actions.
7. Drought risk reduction (prevention, mitigation and preparedness) requires a long-term commitment of resources.

Source: UNISDR (2007)

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