DEVELOPMENT OF A CLIMATE CHANGE VULNERABILITY INDEX FOR PENINSULAR MALAYSIA

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DISSERTATION SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF TECHNOLOGY (ENVIRONMENTAL MANAGEMENT)

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ABSTRACT

There are two factors that can affect changes in climate; internal variation and external forcing. The warming and cooling trend is determined by increases of the concentration of greenhouse gases, which consists of water vapour, carbon dioxide, methane and nitrous oxide. Even if greenhouse gas emissions were stabilised instantly at today's level, the climate would still continue to change as it adapts to the increased emission of recent decades. This is because climate change in the future is greatly influence by the past emissions. Therefore, further changes in climate are unavoidable.

Since 21st century, the issue of climate change has received much attention throughout the world. According to the Fourth Assessment Report: Climate Change 2007 by the Intergovernmental Panel on Climate Change, the increase in surface air temperature is not distributed evenly over the globe. Thus, assessment of the climate change impacts should be carried out at regional scale.

This study provides information on vulnerability to climate change and its magnitude in Peninsular Malaysia at the state level. This assessment was performed through a multivariate index which consists of evaluation from exposure/risk component, sensitivity component and coping ability component. This study used data on the spatial distribution of various climate-related exposure/risk in 11 states and Wilayah Persekutuan Kuala Lumpur. Based on the climate change vulnerability index, the climatically most vulnerable state has been identified so that relevant adaptation strategies and policies can be taken to mitigate the possible threat related to climate change.

The data used in this study was obtained from secondary sources; from the Providing Regional Climates for Impact Studies (PRECIS) and related government agencies. Based on the assessment, Kelantan is the most vulnerable region in Peninsular Malaysia. Kelantan has been recorded as the most vulnerable in 9 risks/exposures out from 15 risks/exposures, namely geographical elevation, road density, potable water supply, communication network coverage, dependency ratio, health facilities, poverty, Gross Domestic Product and air quality. Kelantan scores 0.7061 out of 1.0, as the most vulnerable state towards the climate change in Peninsular Malaysia. Consequently, with the result from this study, the adaptation policy formulation and planning is able to custom based on the risk specific exposure issues related to climate change at the localized level.

ABSTRAK

Perubahan iklim dipengaruhi oleh dua faktor, iaitu perubahan dalaman lazim dan pengaruh luaran dan antropogenik. Trend pemanasan dan penyejukan adalah ditentukan oleh peningkatan kepekatan gas rumah hijau yang terdiri daripada wap air, karbon dioksida, metana dan nitrus oksida. Walaupun pelepasan gas rumah hijau dapat distabilkan pada tahap kini, iklim masih akan mengalami perubahan akibat daripada pelepasan yang terkumpul dari beberapa dekad sebelum ini. Ini kerana perubahan iklim pada masa hadapan amat dipengaruhi oleh pelepasan yang lalu. Oleh sedemikian, perubahan iklim adalah scenario yang tidak dapat dielakkan.

Sejak abad ke-21, perubahan iklim telah mendapat perhatian di seluruh dunia. Menurut Laporan Penilaian Perubahan Iklim Ke-empat 2007 oleh Panel Antara Kerajaan mengenai Perubahan Iklim, peningkatan dalam suhu udara permukaan tidak akan diagihkan secara sama rata di seluruh dunia. Oleh itu, penilaian impak perubahan iklim perlu dijalankan pada skala serantau.

Kajian ini memaparkan maklumat mengenai pendedahan kepada perubahan iklim dan magnitud di Semenanjung Malaysia di peringkat negeri. Penilaian ini dilakukan melalui indeks komposit pelbagai yang terdiri daripada penilaian dari segi komponen pendedahan/risiko, komponen kepekaan dan komponen keupayaan adaptasi. Kajian ini menggunakan data pada taburan pelbagai pendedahan berkaitan iklim/risiko dalam 11 negeri dan Wilayah Persekutuan Kuala Lumpur. Berdasarkan kepada indeks kerentanan perubahan iklim, negeri yang paling rentan dari segi perubahan iklim telah dikenalpasti untuk mensasarkan formulasi adaptasi, perancangan dan pelaksanaan.

Data yang digunakan dalan kajian ini diperolehi daripada sumber-sumber sekunder, iaitu dari Providing Regional Climates for Impact Studies (PRECIS) dan agensi-agensi kerajaan yang berkaitan. Berdasarkan taksiran, Kelantan merupakan negeri yang paling terdedah kepada perubahan iklim di Semenanjung Malaysia. Kelatan telah direkodkan sebagai negeri yang paling berisiko dalam 9 kategori risiko/pendedahan daripada jumlah 15 kategori risiko/pendedahan, iaitu kategori kedudukan geografi, kepadatan jalan raya, bekalan air bersih, liputan rangkaian komunikasi, nisbah tanggungan, kemudahan kesihatan, kadar kemiskinan, Keluaran Dalam Negeri Kasar dan kualiti udara. Kelantan mempunyai skor 0.7601 daripada 1.0, sebagai negeri yang paling rentan kepada perubahan iklim di Semenanjung Malaysia. Oleh yang demikian, dengan hasil daripada kajian ini, penggubalan dasar penyesuaian dan perancangan perlu digubalkan khususnya untuk mengurangkan dan menyesuaikan negeri tersebut kepada perubahan iklim.

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x. National Water Services Commission;
xi. Malaysian Communication and Multimedia Commission;
xii. Department of Statistics; and
xiii. The Prime Minister’s Department.

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API	Air Pollutant Index
AR4	Fourth Assessment Report
BOD	Biochemical Oxygen Demand
CAQM	Continuous Air Quality Monitoring
CFCs	Chlorofluorocarbons
CO_2	Carbon Dioxide
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CH_4	Concentration of Methane
DID	The Department of Irrigation and Drainage
DO	Dissolved Oxygen
DOE	The Department of Irrigation and Drainage
FEWS	Famine Early Warning System
FAO	The Food and Agricultural Organization
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HadCM3	Hadley Centre Coupled Model, Version 3
HDI	Human Development Index
HFCs	Hydrofluorcarbons
HIS	Household Survey Report
IPCC	Intergovernmental Panel on Climate Change
Kendall's W	Kendall's Coefficient of Concordance
MMD	Malaysian Meteorological Department
MOH	Ministry of Health Malaysia

N_2O	Nitrous Oxide
NH_3-N	Ammoniacal Nitrogen
NO_2	Nitrogen Dioxide
NWQS	National Water Quality Standards for Malaysia
O_3	Ozone
PCA	Principal Component Analysis
PLI	Poverty Line Income
PM_{10}	10microns in Size
PWD	Public Works Department
PRECIS	Providing Regional Climates for Impact Studies
SO_2	Sulphur Dioxide
SOPEC	The South Pacific Applied Geo-science Commission
SS	Suspended Solids
TAR	Third Assessment Report
USAID	The United States Agency International Development
UNDRO	The United Nation Disaster Relief Organization
UNFCCC	United Nation Framework Convention on Climate Change
VAM	Vulnerability Analysis and Mapping
WFP	United Nations World Food Programme
WQI	Water Quality Index

CHAPTER 1

INTRODUCTION

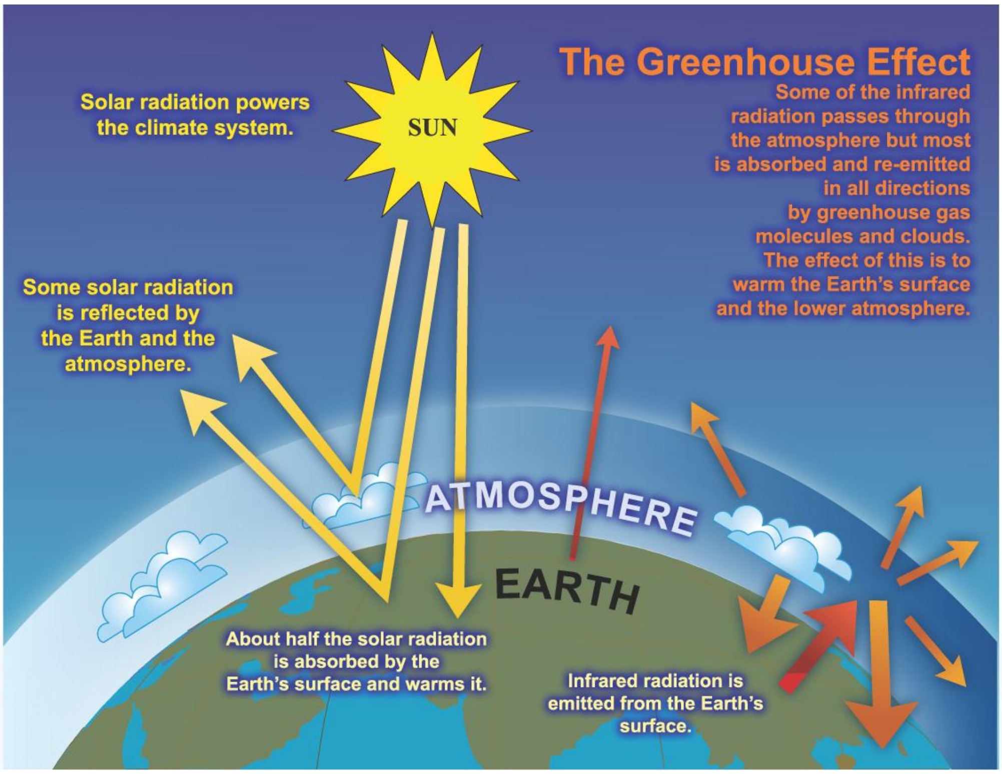
1.1 Climate System and Greenhouse Effects

The climate system is a comprehensive, interactive system of atmosphere, terrain, hydrosphere and biota. Climate is usually described as an average weather of mean and variability of temperature, precipitation and wind over a period, ranging from ten to millions of years (IPCC, 2007). The classical averaging periods is 30 years. The climate system develops under the influence of its own internal dynamics and changes due to external factors or forcings. The external forcings include solar variations, explosive volcanism and human-induced atmospheric composition.

Land use transformation, type and density of vegetation coverage affect the solar heat absorption, water retention and rainfall from the Earth's surface. Changes in composition of atmospheric greenhouse gases affect the amount of radiation retained by the planet. The most critical greenhouse gases blanketing the long-wave radiation from the earth's surface are water vapour and carbon dioxide. In addition, human activities have intensified the blanketing effect through rapid release of greenhouse gases into the atmosphere. Therefore, the chemical composition of the global atmosphere has been dramatically altered by anthropogenic activities, predominantly from the burning of fossil fuels and deforestation (IPCC, 2007).

The greenhouse effect is a natural process. It plays a crucial role in shaping the Earth's climate. As the short wavelength of visible light from the Sun passes through the atmosphere, atmospheric particles and clouds including water vapour reflect approximately 26% of the energy to space. The atmosphere absorbed about 19% of energy and the remaining 55% reaches the Earth's surface (Pidwirny, 2006). Land and ocean reflected only 4% out of the remaining 55% back to space. As a result, about 51% of energy from the Sun reaches the Earth's surface; heating up the Earth's surface and the lower atmosphere as illustrated in Figure 1.1 (IPCC, 2007). Thus, the surface has become a radiator of energy in the long-wave band (infrared radiation) and aids in heating the Earth's surface and the atmosphere. For instance, atmospheric gases including carbon dioxide, methane and water vapour, are able to modify the energy balance of the Earth by trapping the long-wave radiation in the atmosphere. This phenomenon is a naturally occurring and known as the greenhouse effect. However, without the natural greenhouse effect, the average temperature of the Earth's would be cooler instead of its presence 15°C (Richardson et al., 2011). According to Levitus et al., (2001) the concentration and composition of greenhouse gases in the Earth's atmosphere influenced the amount of heat energy accumulated in the atmosphere. Therefore, in the past century, global effects of human activities have become clearly evident in directly or indirectly contributing to variation of the concentration of the principal greenhouse gases such as carbon dioxide and methane.

Air is a mechanical mixture of gases, not a chemical compound. Nitrogen (78.08%) and oxygen (20.95%) are the primary composes the atmosphere. These two most abundant gases occupy approximately 99% (by volume) of the dry atmosphere, exert virtually no greenhouse effect (Houghton,2004; IPCC, 2007; Levitus et al., 2001; Richardson, Steffen & Liverman, 2011; Shepardson, 2011). The remaining are water vapour and trace gases as shown in Table 1.1. Other natural substances may exhibit in undistinguishable amounts such as dust, mold spores and pollen (USEPA, 2011). Water vapour is the most prominent greenhouse gases and dominant contributor to the greenhouse effect. This is follow by carbon dioxide (CO_2), methane, nitrous oxide and ozone.



(Source: IPCC, 2007)

Figure 1.1: The Greenhouse Effect

Table 1.1: Average Composition of the Atmosphere below an Altitude of 25km

Gas Name	Chemical Formula	Volume (%)
Nitrogen	N_2	78.08
Oxygen	O_2	20.95
Water*	H_2O	0 to 4
Argon	Ar	0.93
Carbon dioxide*	CO_2	0.036
Neon	Ne	0.0018
Helium	He	0.0005
Methane*	CH_4	0.00017
Hydrogen	H	0.00005
Nitrous oxide*	N_2O	0.00003
Ozone	O_3	0.000004

Source: Pidwirny, Budikova & Vranes, 2010.
Note: * denotes variable gases.

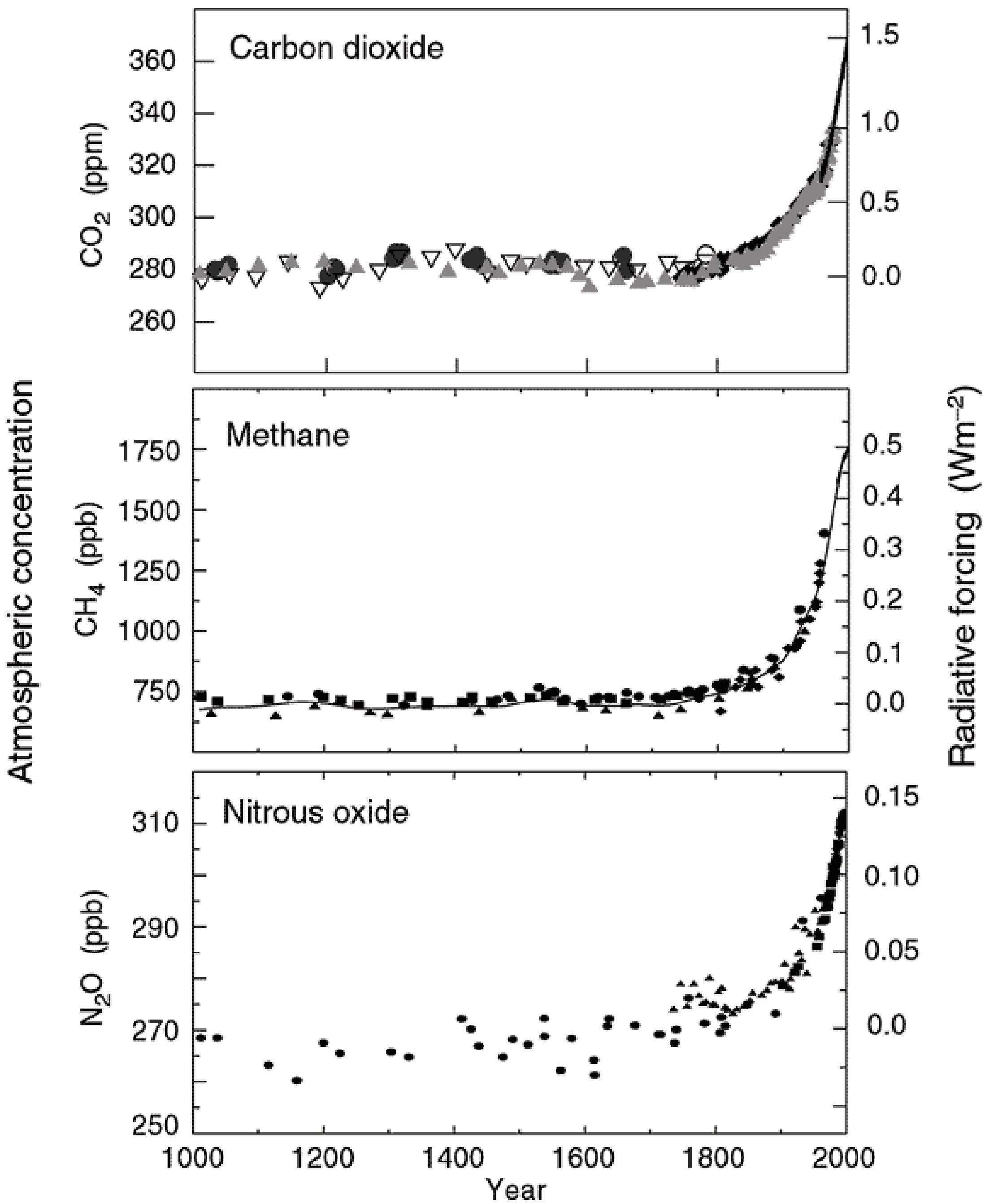
From the Table 1.1, the Earth's most abundant substance among those trace gases in the atmosphere is water vapour. Nevertheless, water vapour is the principle thermal absorber in the atmosphere. According to the research of Freidenreich and Ramaswamy (1993), illustrated that water vapour is capable of accounting about 95% of Earth's greenhouse effect. Concentration of water vapour fluctuates both spatially and temporally between 0% and 4% (Lidzen, 1991). The equatorial zone has the highest concentration. In contrast, water vapour is almost near zero percent in the polar areas. As water vapour is the prevailing greenhouse gas (GHG), warmer temperature will increase evaporation from any water body in the Earth's surface. As a result, changes in its concentration are a consequence of climate feedbacks or forcings. It is clear that human activities do not directly change the water vapour concentration in the atmosphere (IPCC, 2007). On the other hand, anthropogenic activities change the atmospheric concentration and properties that could lead to either warming or cooling of the climate system. Additionally, clouds formation provides an enormous blanket to the warming of the globe. In cloudy weather condition, water vapour under cloudy weather condition is able to absorb up to 85% of infrared radiation, as proposed by Lidzen (1991). Cloud also can increase the albedo, and have a cooling effect on the earth surface.

Even though water vapour is the most influential greenhouse gases, carbon dioxide is a more efficient greenhouse gas. The typical amount of water vapour in the atmosphere is roughly 1% by volume (Barry & Chorley, 2003); which for carbon dioxide, it is nearly 0.04%. Though the concentration of CO_2 is far less that water vapour, it can strongly absorb certain wavelength of the infra-red radiation. Since the Industrial Revolution, it's concentration has been observed to be rising.

Extensive research indicates that variety of ways in which carbon dioxide (CO_2) enters the atmosphere; for example, burning of fossil fuels, land use change; especially deforestation. Carbon sinks (oceans and terrestrial plants) remove billions of tonnes of carbon dioxide from the atmosphere. CO_2 is also being emitted back into the atmosphere annually through natural processes such as volcanic eruption, forest fires, decomposition, digestion and respiration. Carbon sink can be anything that absorbs more carbon that it releases whilst carbon source is anything that have a net emission of CO_2. The natural carbon cycle is in equilibrium when the total carbon dioxide emission is equal to its sequestration.

Since the Industrial Revolution in the 1770's, human industrialization namely, deforestation and burning of fossil fuels, has resulted in an increase of the CO_2 concentration in the atmosphere (Figure 1.2). Urbanization has converted forested areas into the non-forest land use such as arable land, residential land use, industrial land use, and logged area. Carbon sink is eliminated when a vast green area is cleared. In the meantime, when the decomposing process of biomass begins, carbon dioxide will be released. As a result, this interrupts the equilibrium of the carbon cycle. Nearly 12% (Lang, 2009) to 25% (Howden, 2007; IPCC, 2007; Kapos, Herkenrath & Miles, 2007; Matthews, 2006) was estimated to be due by deforestation.

Corinne Le Quéré et al. (2009) reported at least 29% increase in global CO_2 emission is due to the burning of fossil fuel since 2000. Fossil fuel is the foremost carbon sink in the Earth's crust over millions of years. The carbon is not released into the atmosphere as CO_2 due to incomplete decaying of the organism. Nebel and Wright (1981) expressed that every kilogram of fossil fuel burned results in production of three kilograms of CO_2. Therefore, burning of coal, petroleum and natural gas known as fossil fuels, is one of the primary source of carbon dioxide emissions.



Source: IPCC, 2007

Figure 1.2: Indicators of Human Influence on the Atmosphere since the Industrial Era

The concentration of methane (CH_4) had increased about 145% since the Industrial Revolution due to both natural and anthropogenic source (IPCC, 2007). Methane has an atmospheric lifetime of about 9 years (Barry & Chorley, 2003). Methane is a product of microbial fermentative reactions. It is also released from swampland or in rice production. About 60% of the methane emission is due to anthropogenic activities such as agriculture, waste disposal (landfill) and burning of fossil fuel.

Nitrous oxide (N_2O) is the third most notable contributor to radiative forcing of the long-lived greenhouse gases after CO_2 and CH_4 as suggested by Dawson and Spannagle (2009). N_2O is a powerful greenhouse gas and is 300 times more effective absorber of infra-red than CO_2 (Song, 2011; Writers, 2007). The gas is a by-product from biological nitrifications and denitrification processes under aerobic and anaerobic environments, respectively. In reality, atmospheric N_2O has increased 20% over the last century, at a rate of approximately 0.2 to 0.3% per year since the industrial age (refer Figure 1.2). Anthropogenic emissions are originally from agricultural soils (nitrogen fertilizers) and biomass burning. The effect of N_2O to climate change could be detrimental even though N_2O present in an insignificant amount if compared to CO_2 and H_2O. Moreover the long atmospheric residence time of N_2O (132 years) and additional emission from human activities can have a substantial effect on the greenhouse effect (Barry & Chorley, 2003). Climate change particularly global warming may increase the amount of N_2O into the atmosphere as debated by a few researchers (Conner, 2010; Song, 2011; Writers, 2007).

Another greenhouse gases is Chlorofluorocarbons (CFCs) which are a variety of synthetic gases formed of carbon, chlorine and fluorine molecules. CFCs were not present in the atmosphere until 1930s (IPCC,2007). These compounds perhaps are the greatest precursor of climate change in the long run, due to their persistency in the atmosphere (average 65 to 140 years) (Barry & Chorley, 2003). In 1987, many of the world’s nations had agreed to substitute CFCs with hydrofluorcarbons (HFCs) when they signed the Montreal Protocol on Substances That Deplete the Ozone Layer. The Montreal Protocol entered into force in 1989. Although CFCs have been phased out, their long atmospheric lifetimes assure their contribution to the greenhouse effect.

1.2 Climate Change and Extreme Weather

IPCC defines climate change as the changes in climate over an extended period, whether due to natural variability or anthropogenic activity. In addition, the United Nation Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate that attributes directly or indirectly by human activity, which alters the global composition of the atmosphere. The UNFCCC definition focuses exclusively on the effect by human activities.

Many researchers have agreed that even all of the CO_2 emission eliminates immediately; the concentration of greenhouse gases exhibits in the atmosphere will still result global warming in the future (Heltberg, et al. 2008; IPCC, 2007; The World Bank, 2009, Thow & Blois, 2008). Therefore, variation in rainfall patterns and rise of sea-level has been projected from the continuous increment in average temperature (land surface or ocean).

IPCC (2007) reports that significant changes in intensity, areas and frequency of occurrence of extreme weather and climate events including heavy precipitation, droughts, heat waves, and sea-level rise. Observation on climate change hot days, hot nights, heat waves, and heavy precipitation will persist more frequent, and future typical cyclones will become more severe as documented by the IPCC Fourth Assessment Report. Therefore, increase in area affected by droughts and extent of rising sea-level is expected.

Since the mid-20th century, increase of anthropogenic greenhouse gas concentration and composition in the atmosphere associated to global averaged temperature has increased significantly (>90% probability). IPCC Third Assessment Report (TAR) concluded that most of the observed warming over the last 50 year probably (>66% probability) with an increase in GHG emissions are interrelated. IPCC TAR indicated that an average of 0.6°C increased in global average surface temperature over the last century. However, the recent IPCC Fourth Assessment Report (AR4) updated from the figure 0.6°C to about 0.74°C since the beginning of 20th century, with 1998 recorded as the warmest year between 1860 and 2007.

Large variability in climate has been witness around the world over the past few years. In 2005/2006, Asia, Russia and part of Eastern Europe experienced an extremely cold winter condition and warmer winter condition in late 2006/2007. Malaysia has also seen an increase in the number of extreme weather episodes over the past few years, some on a scale not experienced before (Wan Hassan, 2007). It saw devastating monsoon floods affecting the States of Perlis and Kedah in December 2005 (Simon & Othman, 2005). Monsoonal rain with Typhoon Utor, resulted in unprecedented floods in Johor, Melaka, and Southern Pahang in December 2006 and January 2007 (Typhoon Utor to blame, 2006). Wilayah Persekutuan Kuala Lumpur, the capital of Malaysia was badly flooded in March 2009 (Aziz, 2009). Changes in rainfall patterns have caused rivers and canals in northern Peninsular Malaysia prolong dry spell from March till May 2010 (Samy, 2010). Perlis and Kedah once again experienced a serious flood event which breaks the record of once a 100-year flood in November 2010 (Zachariah & Mustaza, 2010).

1.3 Human Vulnerability

Over the recent years, natural disasters caused by climate change observed in most parts of the world. The relationship between human and climate is interrelated. Human activities affect the climate through emissions, while climate affect society through its change, variability and extremes (IPCC, 2007).

Extreme weather events have been witnessed to become more common, more widespread spatially, and more severe. They are a challenge to human society and development. Disaster destructs the gains from development, destroys lives, assets and infrastructure (Heltberg, Jorgensen, & Siegel, 2008). The frequency of climate-related disasters has been 3 to 4 fold more than geological disasters since 1990 (Sanderson, 2002). Climate-related natural disaster will pose more severe impact to the developing and poor countries that are lacking in resources or infrastructure.

Human vulnerability can be defined as the capacity of human and communities in coping, adapting or minimizing the risk to external activities (e.g. the climate change). Threats may arise from a combination of social and physical processes. Adaptability is a characteristic and capacity of the communities to anticipate, resist and recover from the impact of the hazard. Thus, vulnerability has been interpreted as a function of exposure to hazard and adaptability of a certain community.

1.4 Study Area - Malaysia

Malaysia is located between latitudes 1° and 7°N and longitudes 110° and 119° (Federal Research Division, Library of Congress, 2006) in South-East Asia. Malaysia's land is made up of two non-contiguous regions separated about 530 km by the South China Sea (Federal Research Division, Library of Congress, 2006). The Peninsular

Malaysia borders by Thailand at the north, the Strait of Malacca at the west, the Straits of Tebrau (*Selat Tebrau*) at the south and the South China Sea at the east. The other region, East Malaysia, is situated at the northern part of the Borneo Island composing Sabah and Sarawak. Beside Sabah and Sarawak, the Brunei Darussalam and the Indonesia territory Kalimantan together form the Borneo Island. Malaysia also surrounded by many small islands (pulau), the largest being Labuan Island, off the coast of Sabah. The total land area for Malaysia is 329,758 km^2; of which 131,598 km^2 in the Peninsular Malaysia and 198,160 km^2 in Sabah and Sarawak and is administrated into 13 States and 3 Federal Territories (Federal Research Division, Library of Congress, 2006). The total length of coastline boundaries is 2,699 km^2 (Federal Research Division, Library of Congress, 2006). The land boundary between Malaysia is the 506 km bordering with Thailand, 381 km bordering with Brunei and 1,782 km bordering with Indonesia (Federal Research Division, Library of Congress, 2006). The total length of coastline for Malaysia is 4,675 km, which consists of 2,068 km for the Peninsular Malaysia and 2,607 km for East Malaysia (Federal Research Division, Library of Congress, 2006). However, this study will only confine to the Peninsular of Malaysia as shown in Figure 1.3.

Source: Jabatan Perancangan Bandar dan Desa, 2011

Figure 1.3: Map of Peninsular Malaysia

The topography of the Peninsular Malaysia is predominantly characterised by coastal plains with hilly and mountainous in the interior, known as Banjaran Titiwangsa. The Peninsular Malaysia is located just north of the equator and experiences an equatorial climate characterized by warm and humid weather all year round. Temperature and precipitation vary according to their elevation and proximity to the sea but temperature tends to be uniform throughout the year with an annual average temperature ranging from 24°C to 28°C (Malaysian Meteorological Department, 2012). Rainfall is heavy and is under the influence of the Asian monsoonal system with two distinct monsoon regimes, the Northeast Monsoon from November to March, and the Southwest Monsoon from May to September (Malaysian Meteorological Department, 2012). The periods between the monsoons are commonly referred to as the inter-monsoon or transition period where a lot of convectional activities occur causing high-intensity storms of short duration. Total annual rainfall ranges from 1,700 to 4,100 mm in the peninsula (Malaysian Meteorological Department, 2012). Malaysia has relatively high humidity. The mean monthly relative humidity is ranging from 70% to 90%, vary from location and month (Malaysian Meteorological Department, 2012).

The main demographic rates on birth and death data compiled by the Department of Statistics, Malaysia are based on civil registration process provided by the National Registration Department for Peninsular Malaysia. The total population grew from 13.1 million to 22.0 million people from 1980 to the most recent census in 2010. The State with the highest population was Selangor (5.4 million) while Perlis had the lowest population (227,000). From 1980 to 2009, the percentage of urbanization has increased from 25 to 62%. (Department of Statistics, Malaysia, 2010)

Health indicators and infrastructure have improved substantially over the years. These improvements are often attributed to readily accessible health services. However, health problems are still common in lower income State in the country.

Since 1970, Malaysia has transformed from an economy dependent on raw materials production and largely poor-income population to a multi sector economy with a middle-income population. The manufacturing industry of the industrial sector has manoeuvred as the primary source of economic growth since 1980. According to the Department of Statistics Malaysia, the Gross Domestic Product (GDP) grew from 54.3 million to 679,687 million with an average 6.4% annual growth from 1980 to 2009 (Department of Statistics, Malaysia, 2010).

Malaysia faces many natural hazards, particularly flooding (Malaysian Meteorological Department, 2009). Environment with human-induced element often regarded as more complex than natural disasters in the environment. Major source of air pollution is found to be from the automobile emission, however, air pollutants from other sources may contribute to the air quality deterioration in the country. Livestock farming, domestic sewage, land clearing for development and mushrooming of industrial development have contributed to river pollution.

1.5 Scope and Focus of the Study

Within recent two decades, variety of climate change assessment has been conducted to develop scientific knowledge and support the formulation of mitigation and adaptation policies. Mitigation policies aim to minimize or reduce the emissions of greenhouse gases and enhance their carbon sinks. While, adaptation policies are addressing to minimize the climate change impacts and reduce the risk associated with the climate variability and extreme. While, research on mitigation measure has gained much attention, adaptation research should be prioritized. The impacts of climate change are projected to occur, even though we are able to arrest GHG emissions at the present level.

Vulnerability assessment appraised who are the vulnerable groups, where they are vulnerable, and approach to combat the vulnerability. Result of the assessment will be able to assist the decision-makers while targeting the vulnerable groups to maximize the benefits of action taken.

Who are the most vulnerable people? The people who are exposed to a hazard or those who have insufficient ability to survive with the risk exposed, or a combination of both? This query is crucial to prioritise the risk, so the most vulnerable group and their geographical distribution must be identified. Hence, their vulnerability has to be ranked according to the most serious consequences with the less coping capability.

Acosta-Michlik (2005) and Wang et al. (2008) have suggested that multi indicator-based approach suit better for larger-scale studies to identify the vulnerable area at the preliminary stage. Human Development Index, Global-RIMS, Watershed of the World, Water Poverty Index, as well as Environmental Vulnerability Index are an example of vulnerability assessment by using multi indicator based approach. For optimal utilization of limited resources, the outcome of this assessment is highly imperative for decision-makers.

Multi indicators-based approach is a composite of several principal indicators. The generated index provides context and perspective for the public and nontechnical groups to appreciate a vast amount of diverse information.

1.6 Objective of the Study

This study is aimed to develop a vulnerability index of climate change for Peninsular Malaysia. The aims of the assessment model are to

(a) develop and comprehend a regional vulnerability index considering the most significant indicators and sectors contributing to susceptibility to the Peninsular Malaysia;

(b) classify each of states according to their vulnerability to climate change and rank them accordingly.

This information is expected to be highly valuable to decision-makers, as well as external donors in resource-allocation decision on climate change initiatives in national, regional and local scales.

This study aims to increase the awareness and understanding of the impact of climate change within the Peninsular Malaysia. By understanding the current status of climate and considering it from multi-disciplinary perspectives are able to evaluate the future explorations caused by global, regional and local evolutions. This includes examining greatest drivers affecting on the human vulnerability and identifying the vulnerable sub-areas within the Peninsular Malaysia. A major drivers include in this study are natural disaster, social, economical, environmental and physical coping ability.

1.7 Structure of the Study

The first chapter introduces the research topic and scope. Chapter 2 includes a literature review of vulnerability and explains each of the sub-indicators exclusively. The purpose of choosing the sub-indicator and availability of the data for selected year also contributes to determining those sub-indicators.

Chapter 3 introduces knowledge and methods of each sub-indicator such as data provider, description of each station, distribution or year of the selected data. This chapter discusses the stages of development of the Climate Change Vulnerability Index in particular.

Chapter 4 describes the review and evaluation of the developed vulnerability index. This demonstrates the process of developing the vulnerability index computation and analysis of relevant findings.

Chapter 5 discusses the key findings of the newly developed vulnerability index to climate change for the Peninsular Malaysia. The following chapter, Chapter 6 will concludes and summarizes the results and recommendations that lead to future studies

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section presents a review of literature and research which is related to the study. Under the AR4, the IPCC defines climate change as the changes in the state of the climate (i.e. mean and/or the variability of its properties) that can be identified (e.g. using a statistical test) and persists for an extended period, typically decades or longer. It refers to any alteration in climate over a period, whether due to natural variability or result from anthropogenic activity.

According to the AR4 of the IPCC, the description of climate change is mainly focussed on: temperature change, precipitation change, sea-level rise, and extreme events.

(i) *Temperature change* – This dimension is defined or referred as changes in mean temperature over an extended period. The mean temperature may increase or decrease depends on the longitude of a location. However, global warming, the unevenly rise of the average temperature on a global scale will be the main issue with the temperature changes.

(ii) *Precipitation change* – This dimension is defined or referred as changes of precipitation trend or episode over an extended period. This includes an overall increase or reduction in annual and seasonal rainfall.

(iii) *Sea-level rise* – This dimension is defined or referred as increase of the level of the sea over an extended period.

(iv) *Extreme events* – This dimension is defined or referred as changes in frequency and/or intensity of extreme weather events over an extended period. According to the IPCC, heat-waves and heavy precipitations have become more frequent over most of the land areas. Cold days, cold nights and frosts have become less frequent, while hot days and hot nights have become more frequent (IPCC, 2007).

Climate change is among the most challenging issues faced by the society in the 21st century, and it is a process that both reinforces existing inequities, and creates new inequities (IPCC, 2007). There is widespread recognition that the effects of climate change are likely to be highly uneven, with some individuals, households, communities, or regions experiencing significant negative effects, such as the loss of life and property due to climate extremes, the loss of agricultural productivity, increase water stress, damage to infrastructure from the melting of permafrost, and etc. (Adger, 2004; Thomas, 2005; IPCC, 2007; Leichenko & O'Brien, 2008).

Disasters or catastrophic events can cause extreme impacts to human and ecosystems. Disaster result from the combination of both exposure to the climate event and susceptibility to harm by the communities affected (IPCC, 2012). The impacts of disasters include major destruction of assets and the economic, loss and adverse impacts on living organisms and ecosystem.

2.2 Vulnerability

The meaning of the word 'vulnerability' has been varied in diverse fields such as food security, disaster risk, climate change, public health, natural hazard, etc. The term of 'vulnerability' has no a universally accepted definition due to widely used in different areas (IPCC, 2007). Vulnerability to natural hazard and epidemiology has been defined as the degree to which a community is susceptible to being injured by exposure to stress or perturbation circumstances, in conjunction with its ability or capability to cope, recover or develop into a new system or go extinct (Kasperson et al., 2001).

On the other hand, social, economic, and political conditions in the poverty and development literature defines ‘vulnerability’ as a collective measure of human welfare that integrates the environmental, social, economic, and political exposure to a range of catastrophic perturbations (Bohle et al., 1994). According to Yamin et al. (2005), the disaster community defines ‘vulnerability’ as conditions that are determined by physical, social, economic, and environmental factors or processes, and that increase the susceptibility of a community to the impact of a hazard. On the contrary, ‘vulnerability’ is defined as a loss of resilience in the community (Franklin and Downing, 2004). Social vulnerability as mentioned by Adger (1999) has been defined as the exposure of a group or individual to stress duly to social and environmental change, where ‘stress’ refers to unforeseen alterations and disruptions to livelihoods.

Gabor and Griffith (1979) referred ‘vulnerability’ as a risk to which a community is introduced, taking into account not only the properties of the introducer involved but, also the characteristics of the community and the emergency response plan at any point in time.

In addition, Timmerman (1981) describes ‘vulnerability’ as adaptive or coping capability, degree and mode of a system respond to a hazardous event. He also introduced the system’s resilience terms as a measure of the system capacity to absorb, assimilate and recuperate from the adverse event.

According to Cutter (1996), ‘vulnerability’ is the chances of an adversely affected individual or group. It involves the interaction of the hazard or risk introduced and social profile and mitigation of the communities

George Clark (1998) relates ‘vulnerability’ with the combination of two attributes, namely exposure (the risk of experiencing a hazardous event) and the adaptive capability (incorporating resistance and resilience). Resistance is the ability to absorb impacts and continue to function before the system collapse; meanwhile resilience is the ability to recover from damages after an impact or episode of events).

Reilly and Schimmelpfennig (1999) identify ‘vulnerability’ as a probability-weighted mean of losses and profits for instance crop yield vulnerability, farm yield vulnerability, regional vulnerability, and vulnerability to hunger.

Various definitions have been used towards the concept of vulnerability in different international organizations. For example, The Food and Agricultural Organization (FAO) and the United Nations World Food Programme (WFP) are mainly focussed on the vulnerability of food crises. FAO weights all aspects of vulnerability that jeopardize the food security of a community. The degree of vulnerability incorporates the exposure to the risk factors and their ability to survive as well as deal with the stressful situation. The same definition has been used by the WFP in the Vulnerability Analysis and Mapping (VAM) (1999). They defined ‘vulnerability’ as the prospect of an acute shortage of food access below minimum survival levels.

The United States Agency International Development (USAID) determined vulnerability as a proportionate measure in their Famine Early Warning System

(FEWS). 'Vulnerability' argued by the Commonwealth Secretariat (1997) results from occurrence and strength of threat and the ability to withstand the threats (resistance) and to recover to its equilibrium state (resilience). On the contrary, the United Nation Disaster Relief Organization (UNDRO, 1982) has interpreted 'vulnerability' as a degree of damage from the incident resulting from the occurrence of a natural phenomenon of any magnitude.

The South Pacific Applied Geo-science Commission (SOPEC, 1999) has its own definition of vulnerability. Vulnerability has defined as the potential for characteristic of a system to respond adversely to the occurrence of hazardous events, and resilience as the prospective for characteristic of a system to assimilate or minimize the impact of severe events. Environmental vulnerability is a comprehensive and complex with different level of species in the ecosystems and inter-related linkages between them.

In general, vulnerability can be more precisely defined as the risk of extreme event to exposure units or receptors (human, ecosystem and communities) result from the change in climate, social condition and other environmental variables (Clark et al., 2000). The element of vulnerability includes exposure to hazards, sensitivity of the system and coping capacity (Clark et al., 2000; IPCC, 2001; Turner et al., 2003; Adger et al., 2004; Acosta - Michlik, 2005; PIK, 2009; IPCC, 2012).

The IPCC (2007 & 2012), has concluded the vulnerability to climate change as 'the degree to which a system is susceptible or vulnerable to, or unable to manage or recover the adverse effects of climate change (climate variability and extremes), and vulnerability is a function of the nature, extent and rate of climate variation to which a system is exposed, its sensitivity, and its coping capacity'. The vulnerability concept captures both the risk and degree of exposure, and the ability to absorb and recover from the challenges introduced into the environment. Vulnerability to climate change is decisively dependent on the type of hazard and the nature of the environment. The type of definite vulnerability determinants are poverty, health, education, inequality, and governance (Brooks et al., 2005).

In conclusion, vulnerability can be generally characterised as the manifestation of social, economic and community structures. It is mainly concerned with two elements namely exposure to hazard and coping capability of the people. People having more capability to cope with extreme events are naturally less vulnerable to hazard. The severity of the impacts of climate extremes depends strongly on the level of exposure and vulnerability to the events.

2.3 Exposure

Exposure refers to the inventory of environmental elements that a community are exposed to (IPCC, 2012). In this study, the exposure of climate events and natural hazards related to climate change are assessed in terms of frequency, intensity and duration. The extent of impact from weather and climate extremes is largely determine by the combination of physical hazards (such as temperature variances, extreme flood and drought events) and the sensitivity of exposed communities (in terms of social, economic and environmental vulnerability) (IPCC, 2012).

2.3.1 Climate Change Indicator

The greenhouse effect results in possible living life on the planet (IPCC, 2007). Greenhouse gases like carbon dioxide, methane, and water vapour trap some of the energy from the sun to warm the earth's surface to a liveable temperature (Richardson et al., 2011). On the contrary, an overabundance of CO_2, through the anthropogenic activities especially burning of fossil fuel likes coal and oil, are turning the greenhouse effects from a beneficent process into a maleficent episode (Levitus et al., 2001; Richardson et al., 2011). Some evidence of the changing world climate such as increase of averaged surface temperature, sea-level rise, non-polar glacial retreat and melting of ice caps are sign of global warming (IPCC, 2007). Nevertheless, the global averaged surface temperature is the parameter that most clearly defines global warming (Hulme & Viner, 1998; IPCC, 2007). Twelve of the hottest thirteen years ever measured have all occurred since 1995 were recorded in Malaysia (Malaysian Meteorological Department, 2009). Such temperature changes are likely to have impact on the precipitation patterns, sea-level, ecosystem equilibrium and overall human development (IPCC, 2007). In addition, larger climate variability may cause an increase in the frequency of extreme weather events and climate related disasters.

With gradually increasing surface temperature and modified precipitation season, human being becomes more vulnerable. The unfamiliarly high temperature is expected to cause more heat-related illnesses and heat-related deaths.

Besides temperature, climate change effects on the precipitation patterns (Sanderson, 2002; Preston et al., 2006; IPCC, 2007; Thow & Blois, 2008; Füssel, 2009; Sebald, 2010). Extreme precipitation events will increase as the planet warming trend continues. Floods and droughts episodes are expected to increase in frequency and severity (IPCC, 2007; O'Brien & Leichenko, 2007; Dodman, 2009; Salmivaara, 2009). Therefore, records indicate that flooding is the most significant natural hazard and major disaster in the Malaysia, affecting the greatest number of people over the last century (Wan Azli, 2007; Liew, 2009; Begum et al., 2011).

2.3.2 Vulnerability to Natural Hazards

Flood and drought are the natural disasters directly linked with climate change, particularly changes in frequency and intensity of precipitation (IPCC, 2007; O'Brien & Leichenko, 2007; Dodman, 2009; Salmivaara, 2009; IPCC, 2012). Flooding and drought are likely lead to increase the frequency in associated with infectious, respiratory and skin diseases; and finally deaths (Sanderson, 2002; Patnaik & Narayanan, 2005; Chaudhry & Ruysschaert; 2007; IPCC, 2007; Heltberg et al., 2008; IPCC, 2012). Both the events are also likely to have adverse effects on the quantity and quality of surface and groundwater. Hence, the affected quality of potable water supplies will lead to disruption of settlements, commerce, transportations and societies (Thow & Blois, 2008).

Natural hazard or disaster vulnerability deals with susceptibility of the people affected by natural disaster like flood and drought. The impacts of extraordinary rainfall events due to climate change wipe out the gains from development, destroying lives, assets and infrastructures (Rahim et al., 2011). Drought cause impacts to water inadequacy and security (IPCC, 2012). Thereafter, drought leads to reduction and unpredictability in agricultural production which contribute to a negative impact on food security. Besides food security, drought is also associate with forest fires, prevalence of mosquito-borne infectious diseases and an increase stress with the uncertainty of water supply (IPCC, 2012).

Eventually, the consequences of climate change may not be only extreme weather episodes, but also extreme social and financial burdens (IPCC, 2012).

Moreover, extreme weather and increase frequency and/or intensity of natural disasters, such as floods and droughts, will threaten people's lives and may lead to more fatalities, if significant mitigation and adaptation measures are not implemented.

2.4 Sensitivity

This section lists out the sensitivity or vulnerability to hazards, disasters, climate change and extreme events. Sensitivity is a multi-dimensional and complex component of environmental, social and economic elements (IPCC, 2012).

2.4.1 Social Vulnerability

The ability of people in different communities and societies to adapt and cope with changes is very subjective. The vulnerable is a group of people that unable to cope with the adverse environmental impact. Therefore, the social vulnerability comprises basic information on population density, gender distribution, dependency ratio and public health of the group.

According to the IPCC (2007), it has been highly accepted that the effects of climate change will be distributed unevenly around the globe. Specifically in relation to urban areas, the IPCC report states that climate change is almost certain to affect human settlements, large or small, in a variety of significant ways. As a result, high urban densities can both contribute to and reduce the vulnerability of human population (International Global Change Institute, 2000; Hossain, 2001; Heltberg et al., 2008; Dodman, 2009; Salmivaara, 2009; Hoorn, 2010).

Population growth has been accepted as the major drive or key component in sensitivity and vulnerability (IPCC, 2012). Many aspects of urban areas are vulnerable to natural disasters and climate change. For instance, Bangladesh is a densely populated urban area which has encountered with the impacts of climate change (Agrawala et al., 2003; Hoorn, 2010). Dhaka with its population more than 10 million inhabitants has experienced a few severe flood episodes, particularly in 1988, 1998 and 2004 (Alam & Rabbani, 2007). The dense concentration of urban populations can increase the vulnerability to the disasters that are expected to become more intense and frequent as a result of climate change (International Global Change Institute, 2000; Hossain, 2001; Heltberg et al., 2008; Dodman, 2009; Salmivaara, 2009; Hoorn, 2010).

Apart from highly dense urban population, consequences from the climate change are likely to be affect disproportionately to certain vulnerable individuals particularly children, woman, elderly and disabled (International Global Change Institute, 2000; Hossain, 2001; Chaundhry & Ruysschaert, 2007; Hoorn, 2010; Begum et al., 2011).

Gender inequality and climate change are inextricably linked. Women face different vulnerabilities than men especially poor women. In general, people's vulnerability to risk depends in large part on the assets that are available (Sanderson, 2002). Therefore, women tend to have more limited access to assets in terms of physical, emotional, financial, social and natural capital that would enhance their capacity to cope to climate change.

A study done by the London School of Economics that analyzed disasters in 141 countries provided decisive evidence that gender differences in deaths from natural disasters are directly linked to women's economic and social rights (Neumayer & Pluemper, 2007). More women than men will die from disasters when women's rights are not protected. The study also found that in societies where women and men enjoy equal rights, disasters kill the same number of women and men.

The elderly represent a portion of the population that is emerging as highly vulnerable to climate change in the future (IPCC, 2012). Moreover, the elderly often have difficulty adjusting and coping to stressful or changing surrounding conditions, which may lead to depression and ill-health (Cerrato & Trocóniz, 1998).

Climate change will affect human health through heat stress, increasing diarrheal due to water and food-borne disease, facilitate the growth and development of various vector-borne disease (such as malaria and dengue), loss and fatalities from natural disasters, and malnutrition resulting directly from declining yields and/or indirectly through increasing food prices and chemical used or lower demand for agricultural labour (International Global Change Institute, 2000; Hossain, 2001; Chaudhry & Ruysschaert, 2007; Heltberg, 2008; Deressa et al., 2009; Salmivaara, 2009; Hoorn, 2010; Mazrura et al., 2010).

Determinants of human health are extremely diverse ranging from genetic and biological factors through to environmental, social and economic factors. Climate has many potential implications to human health, either the climate enable the formation of a disease or supporting the lifeforms that carry the disease (International Global Change Institute, 2000; Sanderson, 2002; Dodman, 2009). In Malaysia, disease such as dengue and malaria can greatly influenced by the climate and precipitation (Mazrura et al., 2010). The IPCC Fourth Assessment Report has concluded that climate change contribute to the global burden of disease and premature deaths, alter the distribution of infections vector-born disease and increase heat wave related deaths.

2.4.2 Economic Vulnerability

Socio-economic status influences the ability of individuals and communities to absorb the losses from hazards (Peacock et al., 2000; Masozera et al., 2007). Poverty is commonly recognized as one of the most crucial factor contributing susceptibility to adverse environmental changes (O'Brien & Leichenko, 2007; Heltberg et al, 2008; Salmivaara, 2009; Dodman, 2010; Begum et al., 2011).

In general, people living in poverty are more vulnerable than the wealthy (Fothergill & Peek, 2004; Dodman, 2010; Begum et al., 2011). The poor group tends to have much lower coping abilities and is expose to a disproportionate burden of adverse environmental impacts. Poor people have less money to spend on preventative measures, emergency supplies, and recovery efforts. Environmental changes will intensify the stress faced by the poor and deplete, reduce or limit the accessibility of assets and resources required. The IPCC (2007) also states that the poor communities, particularly those concentrated in relatively high-risk areas are more vulnerable than the others. This poorer group are tends to suffer more than the above average or wealthy group in adapting to the effect from climate change (IPCC, 2012). Moreover, more often than not this group are more dependants to natural resources to support their livelihood.

Gross Domestic Product (GDP) is the primary indicator and gauges the economic production within a region, state or country (growth and development) (Department of Statistics, 2011). It is the total dollar value of all goods and services made and purchased within a period given. The GDP measures income, saving, credit purchase, accumulation of capital and standard of living. Generally, the level of economic development of a region with lower GDP is highly dependent on climate variability and extreme weather events (International Global Change Institute, 2000; Hossain, 2001; Patnaik & Narayanan, 2005; Hoorn; 2010). That is, poor society is particularly vulnerable to deviation from average climatic conditions and natural disasters (Begum et al., 2011).

IPCC has identified that climate change is expected to have effects on the overall economic of poor countries, thus hampering potential economic growth. Current extreme weather events are already adding adverse impacts on their economies. Thus, state or regions where climate change exacerbates climatic extremes and where the impact of climatic extremes cannot be well absorbed by their economic capacity will be further constrained in their chances to survive.

2.4.3 Environmental Vulnerability

Human and the environment are dependent on one another. Human being depends on and interacts closely with the natural environment for their survival. They live within the environment, use resources and discharge wastes. Therefore, the environment and resources have been depleted when there are in non-equilibrium status.

Risks to the environmental will eventually translate into risks to human because of their dependence upon the natural environment for resources (Deressa et al., 2009). In turn, the environment is susceptible to both natural events and management by humans. This means that overall vulnerability should include measures of both human and natural systems and the risks. In this section, the environmental vulnerability deals with vulnerability of the people to environmental hazard.

2.4.3.1 Air Pollution

Air pollution is a major health risk that may worsen with increasing industrial activity and consumption of fossil fuel (IPCC, 2007). According to Faridah (2002), exposure to high levels of particulate pollution has long been reported to be detrimental to human health, especially on cardiovascular and respiratory mortality. This evidence has been supported by Ren and Tong (2008), IPCC AR4, (2007), Kan et al. (2012) and Villeneuve et al. (2012).

Extensive research carried out shown that patterns of air pollution is driven by weather (IPCC, 2007, and Ren & Tong, 2008). Therefore, concentration of air pollutants was associated with temperature to affect the health of living creatures.

Ambient air pollution and climate change are placing Malaysian at significant health risks (Wan Hassan, 2007). Hence, the Department of Environment Malaysia has established an ambient air quality monitoring networks located in urban, sub urban and industrial areas throughout the country to detect any significant change in the air quality which may be harmful to human health and the environment. The air quality status is reported in Air Pollutant Index (API). The level and trend of air pollution were characterized according to five (5) principal pollutants, namely ground level of ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and particulate matter of less than 10microns in size (PM_{10}).

2.4.3.2 Water Pollution

Climate change has its direct effects to the water cycle in terms of quality and quantity of water resources (Hossain, 2001; IPCC, 2007; Salmivaara, 2009; IPCC, 2012). Adverse impacts of climate change on water cycle and weather could mean that some regions will become dryer, while the other is facing excessive or abundant of rainfall episode which could leads to major flooding events. Changing water cycles caused by climate change will affect food production, land use and survival of human being (Deressa et al., 2009; Dugard et al., 2010).

As consequences, degradation of water resources and their impact on human health is of immediate concern. Some recent studies have addressed changes in the flow of water and its chemical loads in response to changing land use and climate (Richey et al., 2000; SEA RRC, 2010). Beside quantity, deterioration of water quality polluted with pathogens and toxicants has been documented as a major water-related hazard following extreme hydrologic events including floods (Kouadio et al., 2012).

2.5 Coping Capacity

The IPCC (2007) has distinguished two closely-related terms; adaptation and adaptive capacity. Adaptation is the adjustment in reciprocate to actual or expected climatic stimuli and their effects, which abates harm and exploit beneficial aftermath. On the contrary, adaptive capacity is the ability of a system to regulate effects of climate change. This includes moderate the potential damages, benefit from the opportunities and cope with the consequences.

Meanwhile, the definition and distinction between the term coping and adapting is well discussed in the IPCC 2012 under the Section 1.4 of Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Generally, coping focussed on that particular moment of event occurrence, its constraint and survivability. On the other hand, adapting (in terms of human responses) is focusing on the learning and reinvention in the future.

The extent of human health of affected depends on (i) the exposure of communities to climate change and its consequences, (ii) the susceptibility of the communities towards the effects, and (iii) the ability to cope with the effects (Cutter et al., 2009). Even though the emission rate of greenhouse gases are going to reduce in the near future, the Earth's climate is anticipated to change continuously. Hence, coping ability or adaptive capacity must be considered in order to reduce the upcoming adverse impact of climate change.

Geography or geographical positioning is the one of the most crucial physical coping ability (Preston et al., 2006, Yusuf & Francisco, 2009; Sebald, 2010). Human settlement in low lying areas are at a greater risk of climate change related natural disasters especially flood and intense storm. Extreme rainfall events or prolonged rainfall episodes are common throughout the region resulting in frequent coastal and inland flooding (Preston et al., 2006; Sebald, 2010; Begum et al., 2011).

The other physical coping abilities that able to assist in the respond to humanitarian emergencies are road density, electricity and tele-communication coverage, potable water supply, literacy and availability of health facilities. By improving the transportation (road density), communications and accessibility during natural disaster events to counteract geographical positioning may be considered as one of the best coping ability method.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Vulnerability to climate change is a comprehensive multidimensional process affected by a large number of related indicators. IPCC (2007) defined vulnerability as the degree to which the system is susceptible or vulnerable to, or unable to handle or manage the adverse effects of stresses including climate variability and extremes. Thus, vulnerability is a function of the scale, rate and degree of changes in stresses to which a system is exposed, its sensitivity, its ability to adaptation or adaptive capacity.

3.1.1 Selection of Indicators

Assessment of the current status needs to be done in order to identify which state will be most affected by future challenges. Therefore, climate change vulnerability index towards human population is developed and tailor-made according to the Peninsular Malaysia's circumstances and situation to determine the vulnerable state in Peninsular Malaysia. First and foremost, the decision to adopt a broad or a narrow selection of indicators very much depends on the best available data and representative indicators from Peninsular Malaysia based on the past literatures and research done. Quantitative assessment of vulnerability is usually performed through development of a vulnerability index from several set of indicators. A customized vulnerability index was developed by gathering information from various literatures as shown in Figure 3.1. The multivariate index was used to compare between different states.

Among those vulnerabilities, this study will evaluate the three aspects which are particularly important in this study; therefore, this study intends to address the following:

a) exposure to climate change – relates to the magnitude and rate of change in climatic variables such as temperature and rainfall that are known to impact human population;
b) sensitivity to its effects – the extent to which a community is affected by climate variability or change; and
c) coping capacity for survive with the effects – measure of society's resources and capabilities to offset the unfavourable effects of climate change or exploit potential benefits.

The consolidated index will need to address all three aspects, i.e. exposure, sensitivity, adaptive capacity and is representative of all 11 States and 1 Federal Territory in this study: -

a) Johor;
b) Kedah;
c) Kelantan;
d) Melaka;
e) Negeri Sembilan;
f) Pahang;
g) Perak;
h) Perlis;
i) Pulau Pinang;
j) Selangor;
k) Terengganu; and
l) Wilayah Persekutuan Kuala Lumpur.

Generally speaking, the index is a composite of indicators. The index is powerful because of the ability to synthesize a huge amount of diverse information into a simpler and more useful form. The first indicator, *exposure*, was calculated on an index gauging the strength of future climate change proportionate to today‘s natural variability. This indicator includes annual temperature, rainfall and mean sea-level rise. The second indicator *sensitivity* to climate change was based on indicators expected to increase the frequency of climate shocks (flood, drought, mean sea-level, economic structure, air pollution, water pollution, etc.). The third indicator, *coping capacity* was estimated by combining social (population density, gender distribution and dependency ratio), economy (poverty and GDP) and infrastructure availability.

The methodology and empirical evidence developed in the past capture the multiple dimensions of the uses and advantages of composite indicators. The use of this statistical tool has two main advantages. Firstly, composite indicators summarize a vast and multi dimensional data into a single value. Secondly, with the formation of the single value, they are easier to interpret than a few uncomparable and incompatible data or indicators.

3.1.2 Weightage

The second consideration of the vulnerability index construction is the assignment of weights to selected indicators by giving either equal weights to all indicators or unequal weights in order to produce the final index. When equal weights are given to all the normalized scores simply means weigtage of each indicator is averaged in order to produce the final score. Strict use of equal weigthing is comparatively rare and inappropriate given that the extremely different impact and contribution of indicators to the final score. Yusuf and Francisco (2009) have applied an equal weightage method across the five identified hazards (i.e. cyclone risk, drought risk, flood risk, landslide risk; and sea-level rise) in the Climate Change Vulnerability Mapping for Southeast Asia and received much argument from other peers and researchers. The decision to average the multiple hazards, the population and adaptive capability also received much debate among researchers.

Besides methods with equal weights, there are also methods of unequal weightage (i.e. Iyengar and Sundarshan's method) and multivariate statistical techniques (i.e. Principal Component Analysis).

Principal Component Analysis (PCA) is a simple and non-parametric method for extracting relevant information by reducing the number of dimensions, without much loss of information. Limitation of PCA is mainly due to the fact that PCA is not a statistical method. Therefore, there is no probability distribution involved in the method. Abson et al. (2012) created vulnerability hotspots maps based on principal components analysis (PCA). They argue that the standard practice of averaging or summing indicator scores hides important information regarding the relations between the original variables. Because the principal components (PCs) are uncorrelated, the scores associated with indicators encapsulate a unique aspect of the overall socio-ecological vulnerability represented by the original set of vulnerability indicators.

Iyenger and Sudarshan (1982) developed a method to work out a composite index from multivariate data and it was used to rank the districts in terms of their economic performance. This methodology is statistically proven and compatible with the development of vulnerability to climate change composite index (Kumar, et. al. 2014). In additional, Iyenger and Sudarshan's method proved to be finer compared to both the method of simple averages and PCA.

In conclusion, the vulnerability index of a state in this study was computed using Iyenger and Sudarshan method for each state within Peninsular Malaysia for the year 2012 in order to obtain a holistic concept regarding the vulnerability of various states to climate changes. This method is simple and does not have restrictive assumption of linearity in relation to indicators. Furthermore, it provides the classification of the states based on unequal weightage of the selected indicators. This method was developed to work out a composite index from multivariate data and was used to rank the districts in terms of economic performance by Iyengar and Sudarshan (1982). The selected indexes are further illustrated in Figure 3.1.

a) climate change trends (i.e. temperature and rainfall);
b) climate-related natural hazards (i.e. flood, drought and mean sea-level rise);
c) infrastructure (i.e. geographical elevation, road density, electricity coverage, potable water supply and communication network coverage)
d) human vulnerability (i.e. gender distribution, public health, and literacy);
e) social vulnerability (i.e. population density, dependency ratio and health facilities);
f) economic vulnerability (i.e. poverty and gross domestic product); and
g) environmental vulnerability (i.e. air and water quality).

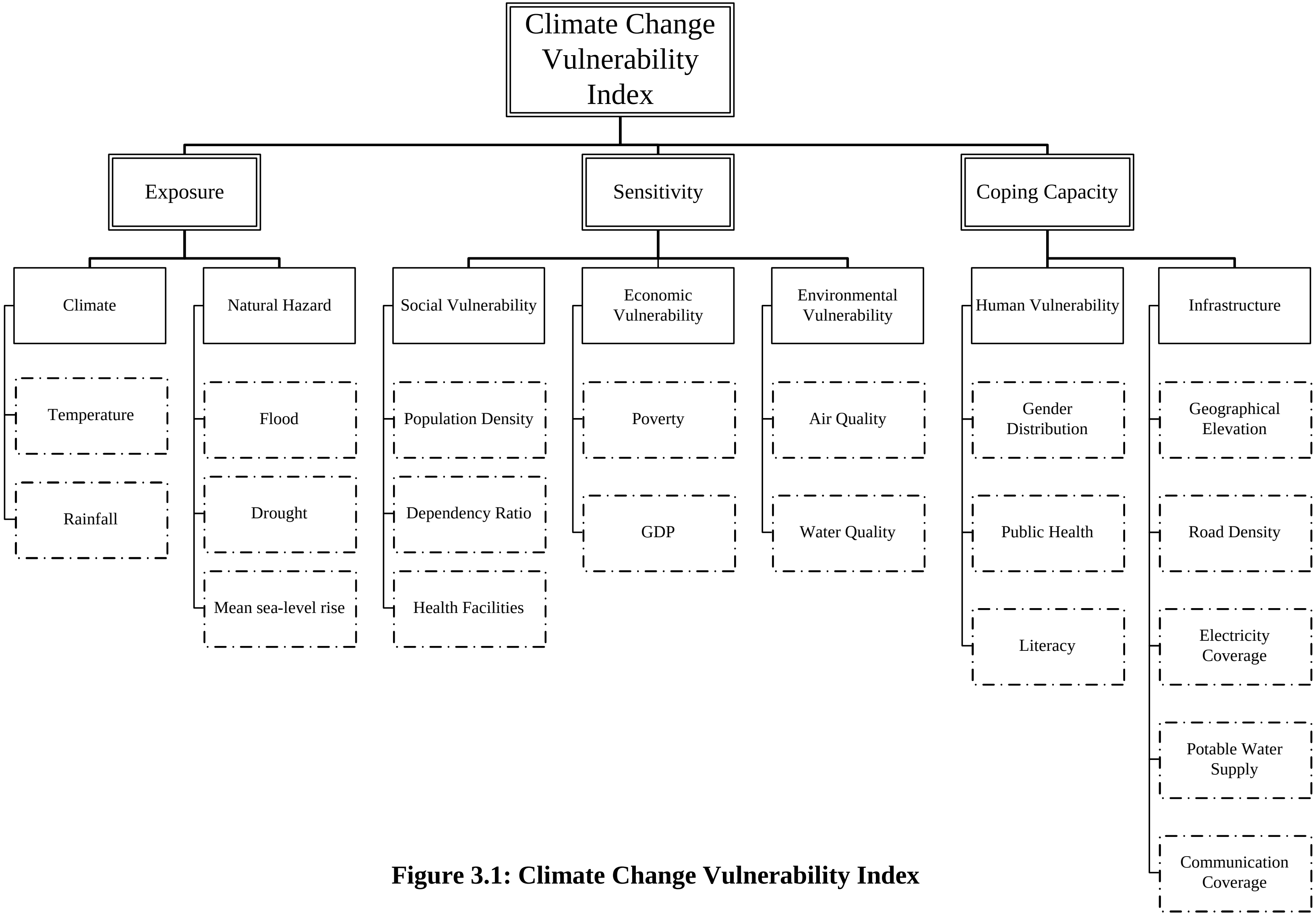


Figure 3.1: Climate Change Vulnerability Index

Generally, development of the vulnerability index consists of several steps. A series of data from several government agencies were gathered, and regression analysis took place. The averaging of multivariate indicator has to be ‘standardized’ or ‘normalized’ since the indicators of the index are usually measured in different units. The vulnerability indices are then computed for each state from unequal weightage. Then, the state was ranked according to their vulnerability index computed.

3.2 Climate – Temperature and Precipitation

Increasing concentration of GHG in the atmosphere is believed to be the primary culprit of global warming. Recorded surface temperature has become the evidence of warming earth’s climate. The AR4 discovered a new finding that global average temperature has increase a total of 0.74°C in over the last 100 years.

Extreme precipitation events, which include heavy rainfall and extraordinary long spell of dry days (drought), are among the most disruptive atmospheric phenomena. The IPCC AR4 indicated that frequency and intensity of some extreme weather events were more severe and unpredicted over the last 50 years (1900 to 2005). For example, a more frequent heavy precipitation event or increase in frequency or proportion of total rainfall from heavy falls globally (IPCC, 2007).

In this study, regional climate model simulation for the Peninsular Malaysia was based on the second generation Hadley Centre regional climate model known as Providing Regional Climates for Impacts Studies (PRECIS). PRECIS is a model of the atmosphere, hydrosphere and land which is locatable over any part of the globe. PRECIS is a high-resolution climate modelling system with a nominal resolution of 50 km^2. PRECIS is able to represent most of the fundamental physical processes within the climate system and is formulated from dynamical flow, cloud, radioactive processes, precipitation, atmospheric aerosols and soil hydrology. PRECIS is a limited area regional models requiring meteorological information at its lateral boundary conditions. The climate of a region is always strongly influenced by the global environment.

The data assessment of climate data set is conducted over a minimum period of 30 years. Furthermore linear regression is an appropriate method to assess change over a minimum period. The annual temperature variation pattern and rainfall distribution simulated by the PRECIS was compared to the temperature trend observed by the Malaysian Meteorological Department (MMD).

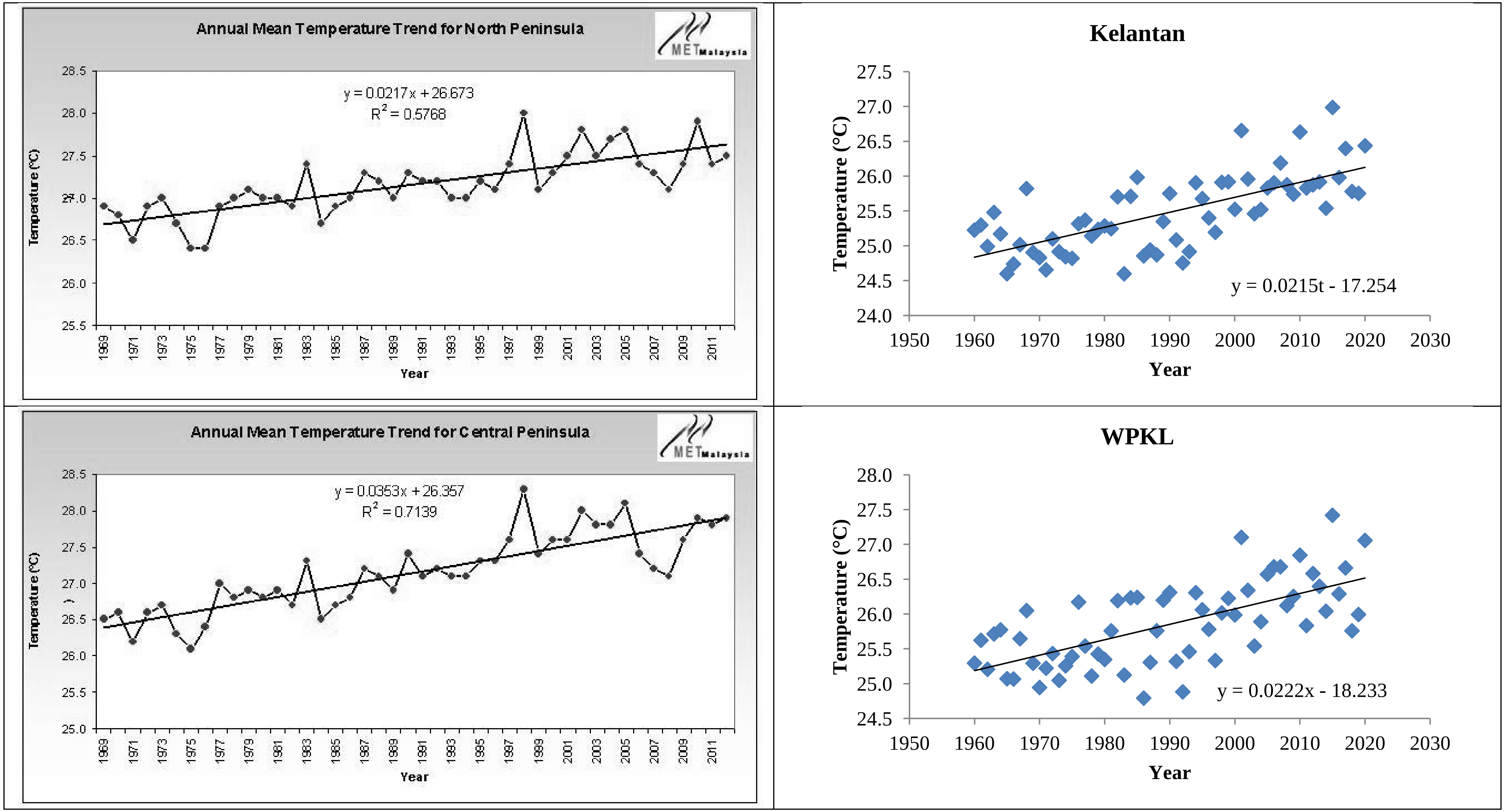
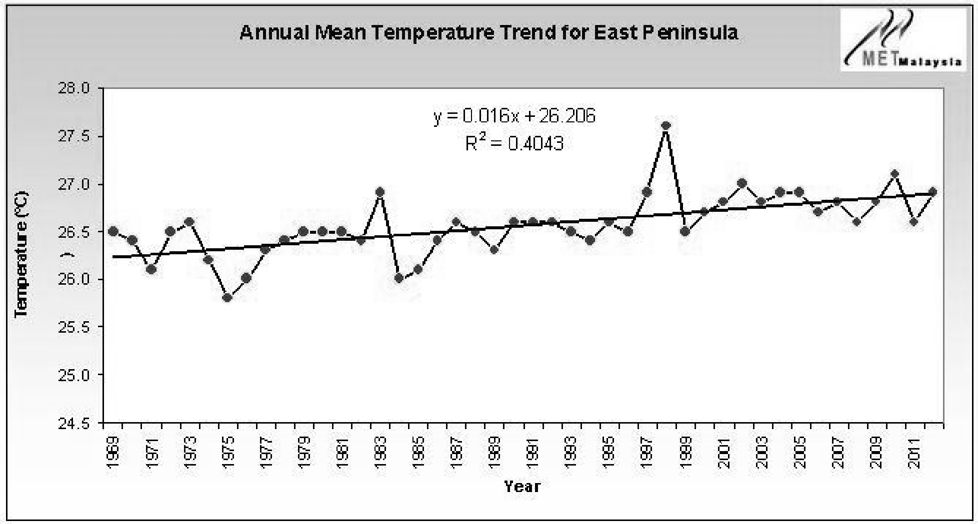
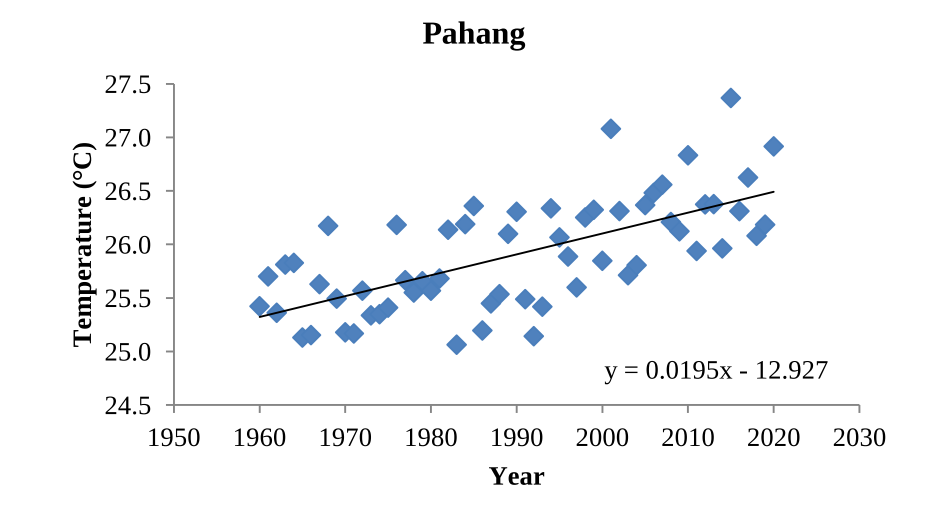
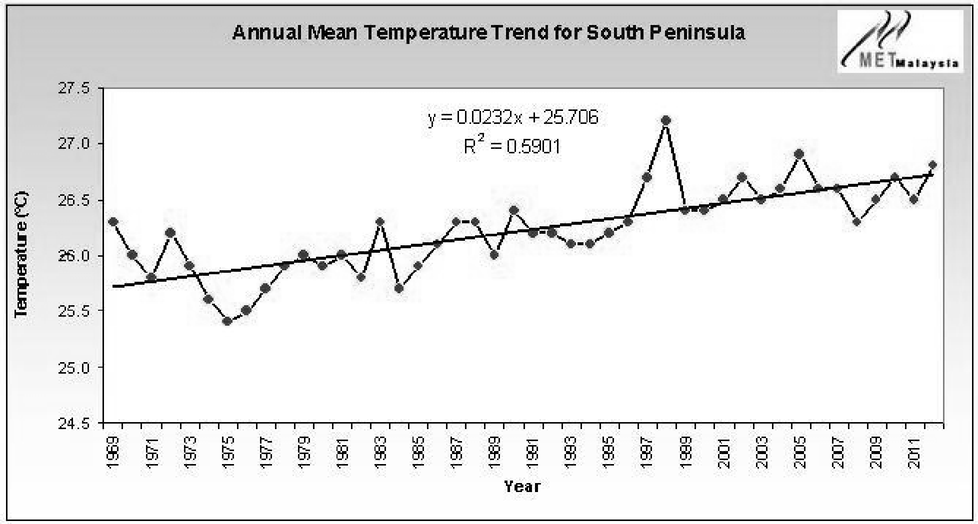


Figure 3.2: Annual Mean Temperature Trend for Observation and Predicted Data derived from PRECIS







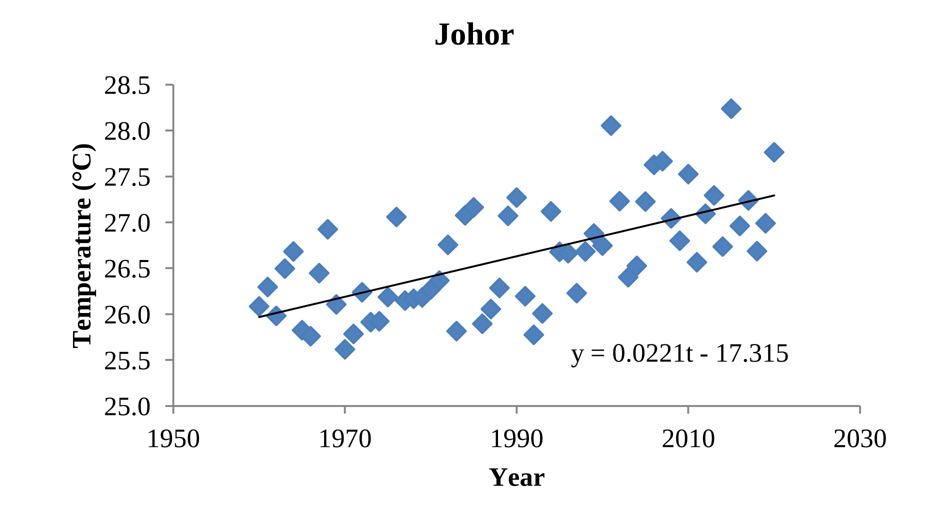
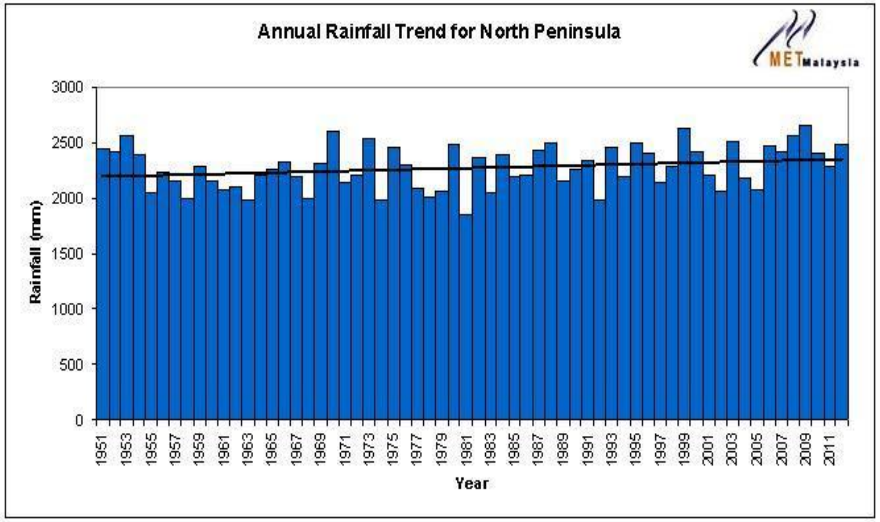
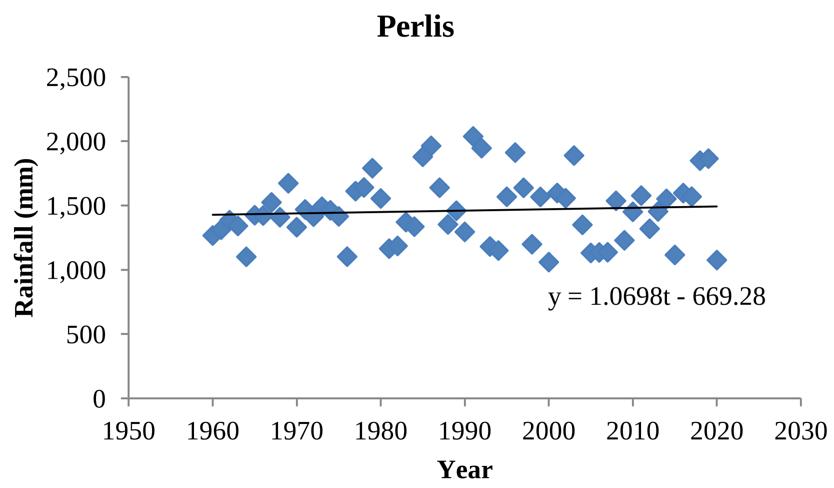
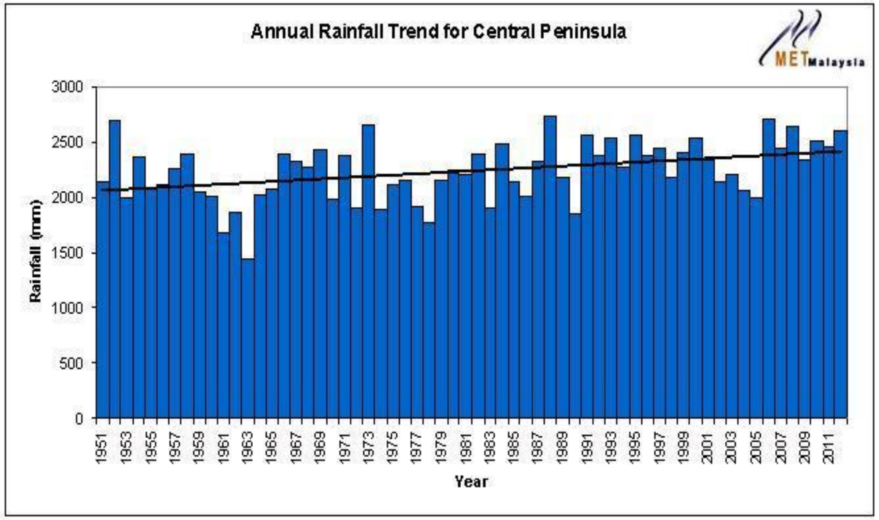


Figure 3.2: Annual Mean Temperature Trend for Observation and Predicted Data derived from PRECIS (cont')







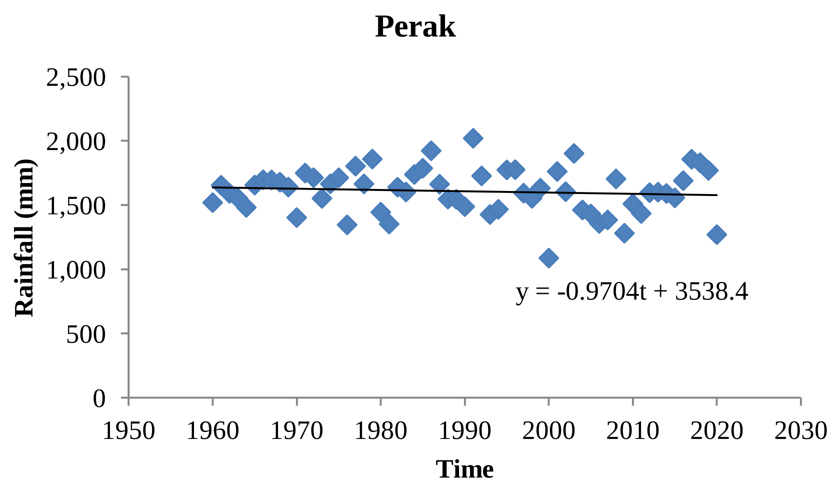
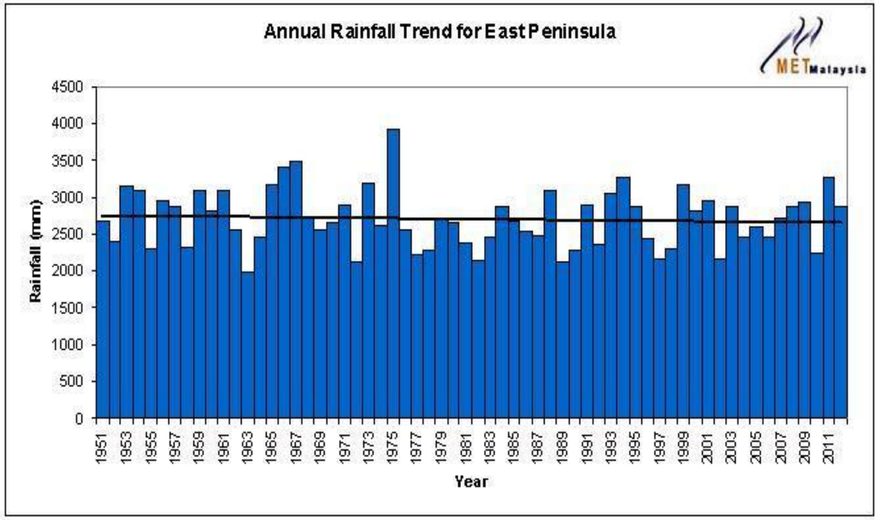
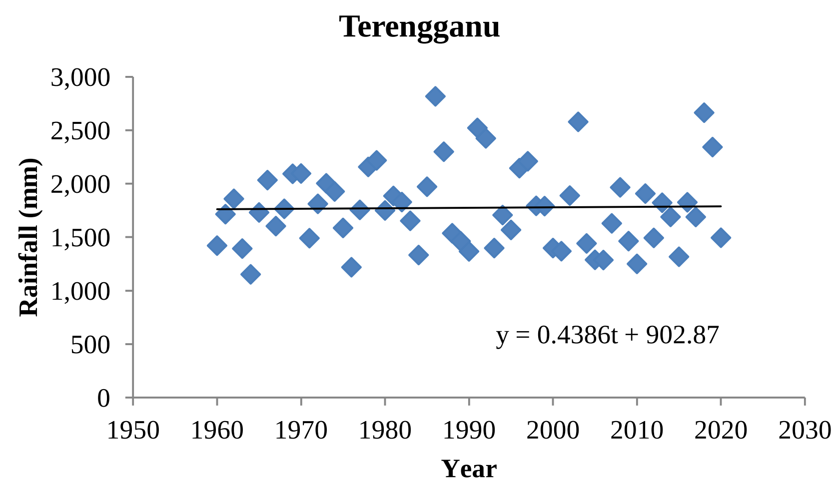
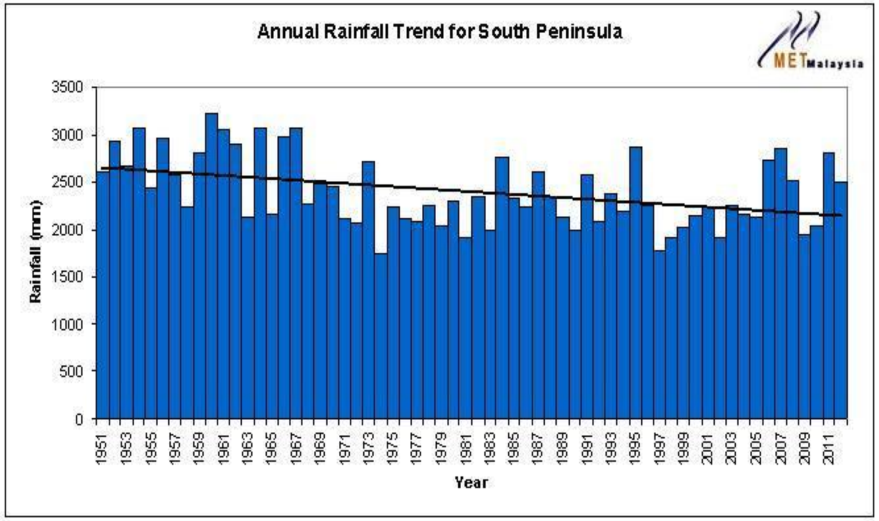


Figure 3.3: Annual Rainfall Trend for Observation and Predicted Data derived from PRECIS (cont')







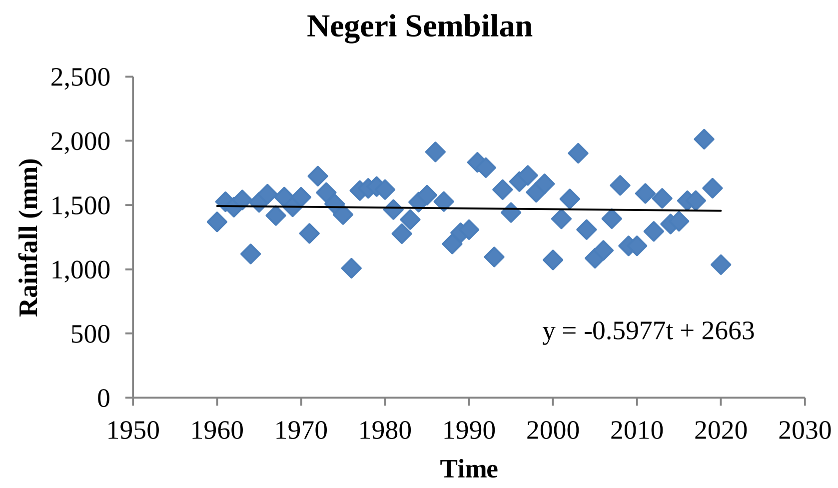


Figure 3.3: Annual Rainfall Trend for Observation and Predicted Data Derived from PRECIS (cont')

Figure 3.2 and Figure 3.3 show the annual mean temperature and rainfall trend between the observed data by MMD and model data derived from PRECIS, respectively. As presented in the Figure 3.2, the annual mean temperature trend predicted for Kelantan, WPKL, Pahang and Johor are having the similar trend and correlation with the annual mean temperature trend observed at north, central, east and south of Peninsular Malaysia, respectively. Almost the same trends were observed for the annual rainfall trend except for the central of Peninsular Malaysia. There is a positive correlation observed for the Central of Peninsular Malaysia by the MMD while the PRECIS predicted a slight decrease trend for Perak. Overall, the data are provided by global general circulation model, HadCM3, the Hadley Centre's state-of-the-art coupled model and is consistent with the observational data. Hence, mean surface temperature and the amount of rainfall for Peninsular Malaysia obtained from the PRECIS from 1960 – 2020 were used for the tabulation in this study.

3.3 Natural Hazards – Flood, Drought and Mean Sea-level

Water-related extreme, floods and droughts, have happened more frequently with warmer climate and increase climate variability. Flood is an overflow of an expanse of water that inundates land, when a channel cannot convey the total flood flow and water will spill beyond the channel. In contrast to flood, drought results from pro-longed low rainfall possibly accompanied by high temperature.

The information of hydrology and water resources denotes for the flood indicator for the Peninsular Malaysia was provided by the Department of Irrigation and Drainage (DID) Malaysia. The monthly hydrological input of water level as tabulated under the Table 3.1 for each state from year 1983 – 2012 was collected, collated and analysed.

Table 3.1: Hydrological Data for Flood at Major River Basins in Malaysia

State	Water Level Station	Coordinate	
		Latitude	Longitude
Johor	Air Itam, Sg Sembrong	01° 56' 20"	103° 09' 40"
Kedah	Jam. Syed Omar, Sg Muda	05° 36' 35"	100° 37' 35"
Kelantan	Jeti Kastam, Sg Kelantan	06° 08' 00"	102° 14' 00"
Melaka	Klebang Besar U/S, Sg Malim	02° 13' 58"	102° 12' 10"
Negeri Sembilan	Titan Bintagor, Sg Rembau	02° 28' 22"	102° 06' 00"
Pahang	Pasir Kemudi, Sg Kuantan	03° 52' 12"	103° 11' 24"
Perak	Teluk Sena, Sg Perak	04° 15' 20"	100° 54' 00"
Perlis	Kg Sg Bakau, Sg Arau	06° 25' 40"	100° 16' 25"
Pulau Pinang	Jln P.Ramlee, Sg Pinang	05° 24' 38"	100° 19' 02"
Selangor	Rantau Panjang, Sg Selangor	03° 24' 10"	101° 26' 35"
Terengganu	Jambatan Jerangau, Sg Dungun	04° 50' 35"	103° 12' 15"
WPKL	Jambatan Petaling, Sg Klang	03° 04' 51"	101° 39' 55"

Source: Department of Irrigation and Drainage, 2013.

At the same time, the data for number of no raindays was obtained from the DID denotes the drought parameter. Due to the data availability throughout the period from 1983 to 2012, the data for drought parameter was not able to be obtained from each of the states. The data obtained was categorized to represent the north-western region (which consists of Perlis, Kedah, Pulau Pinang and Perak), north-eastern region (which consists of Kelantan, Terengganu and Pahang) and southern region (which consists of Selangor, Wilayah Persekutuan Kuala Lumpur (WPKL), Negeri Sembilan, Melaka and Johor). Details of the rainfall station were listed under Table 3.2.

Table 3.2: Rainfall Station for Drought Parameter

Region	Rainfall station	Coordinate	
		Latitude	Longitude
North-western region	Pejabat Daerah Kampar, Perak	04° 18’ 20”	101° 09’ 20”
	Stor JPS Alor Setar, Kedah	06° 06’ 20”	100° 23’ 30”
North-eastern region	Setor JPS Kuala Terengganu, Terengganu	05° 19’ 05”	103° 08’ 00”
	Stor JPS Kota Bharu, Kelantan	06° 06’ 30”	102° 15’ 25”
Southern	Setor JPS Johor Bahru, Johor	01° 28’ 15”	103° 45’ 10”
	Setor JPS Endau, Johor	02° 39’ 00”	103° 37’ 15”

Source: Department of Irrigation and Drainage, 2013.

Information for Malaysian mean sea-level change was referred to study done by Md. Din et al. (2012). The research has been carried out to study the long-term mean sea-level changes from 1983 to 2008. There are a total of 12 tidal stations has been studied as listed under Table 3.3.

Table 3.3: Tidal Stations within Peninsular Malaysia

Region	Tide gauge station
North-western	Pulau Langkawi, Kedah
	Pulau Pinang
	Lumut, Perak
North-eastern	Pulau Tioman, Pahang
	Tanjung Gelang, Pahang
	Chendering, Terengganu
	Getting, Kelantan
Southern	Port Klang, Selangor
	Tanjung Keling, Negeri Sembilan
	Kukup, Johor
	Johor Bahru, Johor
	Tanjung Sedili, Johor

Source: Md Din et al., 2012.

3.4 Infrastructure – Elevation, Road Density, Electricity Coverage, Water Supply and Communication Network Coverage

Geographical elevation is one of the key indicators to show vulnerability of a region. A lower elevation of a location poses much higher flooding risk. The average elevation of a state was extracted from PRECIS model.

The infrastructure in a society is able to maximize gains and minimize losses from climate change. The improved quality of living standard at each state will allow the population to regulate the impact of climate change accordingly. The infrastructures, amenities, facilities and services available for evaluating the climate change impact as summarized in Table 3.4.

Table 3.4: Indicators in Evaluating Coping Capacity to Climate Change

Indicator	Description	Source
Geographical Elevation	Average elevation of a state	PRECIS
Road density	Road length over the total area of a state	Public Works Department
Electricity coverage	Percentage the area which received electrical supply	Tenaga Nasional Berhad
Potable water Supply	Percentage of the area which received treated water supply	National Water Services Commission
Communication Network Coverage	Number of fixed-line telephone and mobile phone per 1,000 population	Malaysian Communication and Multimedia Commission

3.5 Human Vulnerability – Gender Distribution, Public Health and Literacy

The extent and ability of each individual to adapt to and cope with the impact of environmental changes are varied among others. According to the United Nation Inter-Agency Network on Women and Gender Equality, the threat of climate change is not gender neutral. In general, women are more vulnerable to the effects of climate change than men primarily in the developing and natural resources dependant countries. Therefore, sex distribution of a society in the year 2012 was used. Sex distribution is the ratio of the number of male for every female as according to the Department of Statistics Malaysia.

$$Sex\ ratio = \frac{number\ of\ males}{number\ of\ females}$$

The AR4 by IPCC reported that climate change contributed to the global burden of disease. Changing in climatic conditions can affect human health indirectly through heightened risk of infectious disease epidemics. The information of the incidence rate for dengue and malaria as per 100,000 inhabitants for each of the states was obtained from the Ministry of Health Malaysia (MOH).

Literacy rate determine by the percentage of adult (> 15 years old) able to read and write. With the ability to understand, communicate and interactive, the impact of climate change is able to distribute to the designated group of vulnerable. The data of literacy rate for year 2012 was obtained from the Ministry of Education.

3.6 Social Vulnerability – Population Density, Dependency Ratio and Health Facilities

The demography statistics including population density and dependency ratio for each of the state were obtained from the Department of Statistics Malaysia. Distribution of the population such as population density, and dependency ratio, determine the vulnerability of a region.

The size and the total population (for year 2012) for each state were obtained. The population density was calculated based on population per unit of the land area.

$$Population\ density = \frac{Population}{Land\ area}$$

Age distribution provides the statistic of the population according to age group of 0 – 14 years old, 15 – 64 years old, 65 years old and above. The socio-economic and demographic of a population affect a nation's coping ability to climate change shocks. Children within the age group of 0 – 14 years old and senior citizens or elderly (65 years old and above) are consider to be more vulnerable than adult (ranging from 15 – 64 years old). Therefore, the age distribution is a ratio of the number of children and elderly over the number of adult in the year 2012 for the 11 States and 1 Federal Territory. Some groups are more exposed to certain environmental risks than others. The very young and the old are often identified as more vulnerable groups.

$$Age\ Distribution = \frac{Number\ of\ children\ \&\ elderly}{Number\ of\ adult}$$

The health facilities in this study refer to the number of hospital beds per population. This data shows the availability and readiness of the health facilities support to the society in the case of any outbreak of disease occur. The data for year 2012 was obtained from the Ministry of Health Malaysia.

3.7 Economic Vulnerability – Poverty and Gross Domestic Product

The understanding of the concepts of poverty and Gross Domestic Product (GDP), vulnerability and their linkage are crucial in the efforts to improve the standards of living in the Peninsular Malaysia. In this study, poverty is defined as circumstance when the gross monthly income of a household is insufficient to sustain minimum necessities of life. The GDP measures the economic production of a particular state in year 2011. Vulnerability has been closely associated with poverty and GDP of a state. The information of poverty incidence and GDP for year 2011 was provided Economic Planning Unit, the Prime Minister's Department.

3.8 Environmental Vulnerability – Air Quality and Water Quality

The degradation resulting from climate change increases the vulnerability to basic environmental asses, especially air and water quality. The polluted environmental components and degradation of pristine quality has increased the vulnerability as climate change.

Air pollution is defined as introduction of gases, particulate matters, or biological materials that cause any harm to the living organisms and disturb the equilibrium of the atmosphere. Air pollution is one of the most serious environmental issues in the majority countries regardless their economic development. In developing and developed countries, majority people are exposed to high level of indoor air pollution. In industrial countries, urban and metropolitan citizen are subjected to higher concentration of air pollutants especially particulate matters, sulphur dioxide and nitrogen dioxide due to burning of fossil fuels. The combustion of fossil fuel leads to emissions of GHG, carbon dioxide in particular, as well as methane and nitrous oxide. Accumulating of these GHG in the atmosphere is reported to cause warming effect the earth's surface. In Malaysia, the concentration or level of air pollutant present in the ambient air was closely monitored by the Department of Environment Malaysia (DOE).

The DOE has establish a network of Continuous Air Quality Monitoring (CAQM) stations to measure the concentration of five (5) principal pollutants in the ambient air, namely, suspended particulate matters (PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3). Number of good API days (0-50) from CAQM stations was chosen to represent the air quality status. The data was gathered and grouped into three different regions, namely, north- western, north-eastern and southern regions.

Approximately 70% of Earth's surface consists of water. However, only a small amount of the fresh water (approximately 1% of the total water present in this Earth) is consumable by the human being. Therefore, this small amount of consumable water, water pollution has emerged as a serious public health. Population increasing, rapid urbanisation and industrial developments were affecting the quality of water.

The DOE maintains continuous water quality monitoring stations throughout the whole Malaysia for early detection of pollution influx. The water monitoring results are presented in the form of Water Quality Index (WQI) and categorized into three different regions by designated states.

WQI is a tool/indicator to evaluate water quality and allows categorization of pollution load and classes of beneficial uses as stipulated under the National Water Quality Standards for Malaysia (NWQS). THE WQI was derived from Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3-N), Suspended Solids (SS) and pH.

3.9 Normalization of Indicators using Functional Relationship

The indicators used in this study are measured in different units and scales. According to the United National Development Programme's Human Development Index (HDI), the figure has to be free from unit. Thus, normalization is carried out to standardize their values between 0 and 1. Before normalization, functional relationship between the indicators and vulnerability has to be identified. There are two (2) types of functional relationship; either vulnerability increase with an increase with the value of the indicator or decrease with the value of the indicator. In the case, where vulnerability increase corresponding to the value of the indicator (the variables have ↑ functional relationship with vulnerability), Equation 1 will be adopted for normalisation.

$$Xi = \frac{Xi - Min\{Xi\}}{Max\{Xi\} - Min\{Xi\}}$$

On the other hand, normalization of vulnerability increase with a decrease with the value of the indicator (the variables have ↓ functional relationship with vulnerability) is shown in Equation 2.

$$Yi = \frac{Max\{Xi\} - Xi}{Max\{Xi\} - Min\{Xi\}}$$

The normalization of the indicator value could takes into account the functional relationship between the variable and vulnerability which is important in the construction of the indices. Functional relationship with climate change of the indicator used in this study was summarized in Table 3.5.

Table 3.5: Functional Relationship with Climate Change

Component	No	Indicator	Functional Relationship with climate change
Climate Change Parameter	1	Change in monthly average temperature	↑
	2	Change in monthly precipitation	↑
Climate related Natural Hazards	1	Change in river water level	↑
	2	Number of no raindays	↑
	3	Rise in mean sea-level	↑
Infrastructure	1	Geographical elevation	↓
	2	Road density	↓
	3	Electricity coverage	↓
	4	Potable water supply	↓
	5	Communication network coverage	↓
Human Vulnerability	1	Gender distribution	↓
	2	Public health	↑
	3	Literacy	↓
Social vulnerability	1	Population density	↑
	2	Dependency ratio	↑
	3	Health facilities	↓
Economic vulnerability	1	Poverty	↑
	2	Gross Domestic Product (GDP)	↓
Environmental vulnerability	1	Change in Air Pollution Index (API)	↓
	2	Change in Water Quality Index (WQI)	↓

Weight, *w* for each indicator lies between 0 and 1, diverge inversely as the variation in the respective of development indicators as shown in Equation 3, where 1 indicating maximum vulnerability and 0 indicating no vulnerability at all. The choice of this weight would ensure that large variation of the indicators would not excessively dominate the input of the rest of the indicators and distort inter-state comparisons.

$$Wi = \frac{c}{\sqrt{Var.(Vi)}}$$

where c = normalizing constant where

$$c = \left[\sum_{i=0}^{n} \frac{1}{\sqrt{Var.(Vi)}}\right]^{-1}$$

3.10 Statistical Tests on Vulnerability Indices

The degree of correlation between components of vulnerability can be examined by testing the significance of rank correlation coefficients between them. The component rank can be used to assess the unanimity among the components of vulnerability. When there are more than two components, Kendall's coefficient of concordance for ranks (also known as Kendall's W) can be an extremely useful tool in the assessment of data relationships where several dependent and independent variables could be considered simultaneously. Kendall's W calculates agreements among three or more rankers as they rank a number of subjects according to a particular characteristic. Kendall's W is defined as

$$W = \frac{12S}{m^2(n^3 - n)}$$

where *S* is the sum of squared deviations, *m* is the number of components and *n* is the number of states.

$$S = \sum_{i=1}^{i=n} (R_i - \bar{R})^2$$

R_i = sum of the rank of state *i* and mean value of total ranks,

$$\bar{R} = \frac{m(n+1)}{2}$$

Kendall's W lies between 0 (no agreement) and 1 (complete agreement), where W = 1 indicates that there is perfect unanimity among the different components in ordering the states. On the other hand if W = 0, there is no overall trend of agreement among the components in ranking the states. The significance of Kendall's W can be tested by

$$X^2 = m(n-1)W$$

which has a chi-square distribution with $(n - 1)$ degrees of freedom.

CHAPTER 4

RESULTS

4.1 Introduction

The review and evaluation of the newly developed vulnerability index for Peninsular Malaysia is discussed in this chapter. There are a total of 20 parameters selected based on the three components of vulnerability – exposure, sensitivity and coping capacity. These selected indicators are to be assessed and collated into the respective risk or sensitivity map of Peninsular Malaysia. Finally, a climate change vulnerability map for the Peninsular was overlaid with the significance sub-index maps. The climate change vulnerability map shows the least to the most susceptible states within Peninsular Malaysia. In order for the policy or decision maker to develop and implement appropriate responses and adaptation strategies, it is essential to establish a comprehensive baseline of the current situation in Peninsular Malaysia and an understanding of the effects of climate change, the degree of vulnerability and the national adaptation capacity.

These three components – exposure, sensitivity and coping capacity – are highly inter-related and develop continuously (IPCC, 2012).

4.2 Exposure

4.2.1 Temperature

The annual temperature data was gathered from PRECIS, a predicted regional climate model based on second generation Hadley for Peninsular Malaysia from 1960 – 2020.

The data was obtained, collated and plotted as a linear graph (temperature vs year). Figure 4.1 shows the trend of average annual surface temperature for each of the states within the Peninsular Malaysia. Malaysia, like most parts of the globe, has experienced increasing temperature. The graph of predicted surface mean temperature for Negeri Sembilan during the period 1960 to 2020 indicated an increase of 1.38°C or an average 0.023°C per year increase. This follows by WPKL (+1.33°C), Perlis (+1.33°C), Johor (+1.32°C), Melaka (+1.31°C), Kelantan (+1.29°C), Selangor (+1.25°C), Kedah (+1.22°C), Terengganu (+1.21°C), Perak (+1.19°C), Pahang (+1.17°C), and Pulau Pinang (+1.08°C) finally from 1960 to 2020.

A positive value indicates that the temperature increased over the years. Moreover, the increasing trend is in agreement with extensive research carried out by various academicians/researchers/government agency throughout the years (Sanderson, 2002; Kimoto, 2005; Patnaik & Narayanan, 2005; Preston et al., 2006; IPCC, 2007; Thow & Blois, 2008; Füssel, 2009; Malaysian Meteorological Department, 2009; Yusuf & Francisco, 2009; Xu et al., 2009; Sebald, 2010; Begum et al., 2011). Most of the states show a consistent increase in temperature throughout the year. Negeri Sembilan showed highest regional temperature increase compared to other states within Peninsular Malaysia.

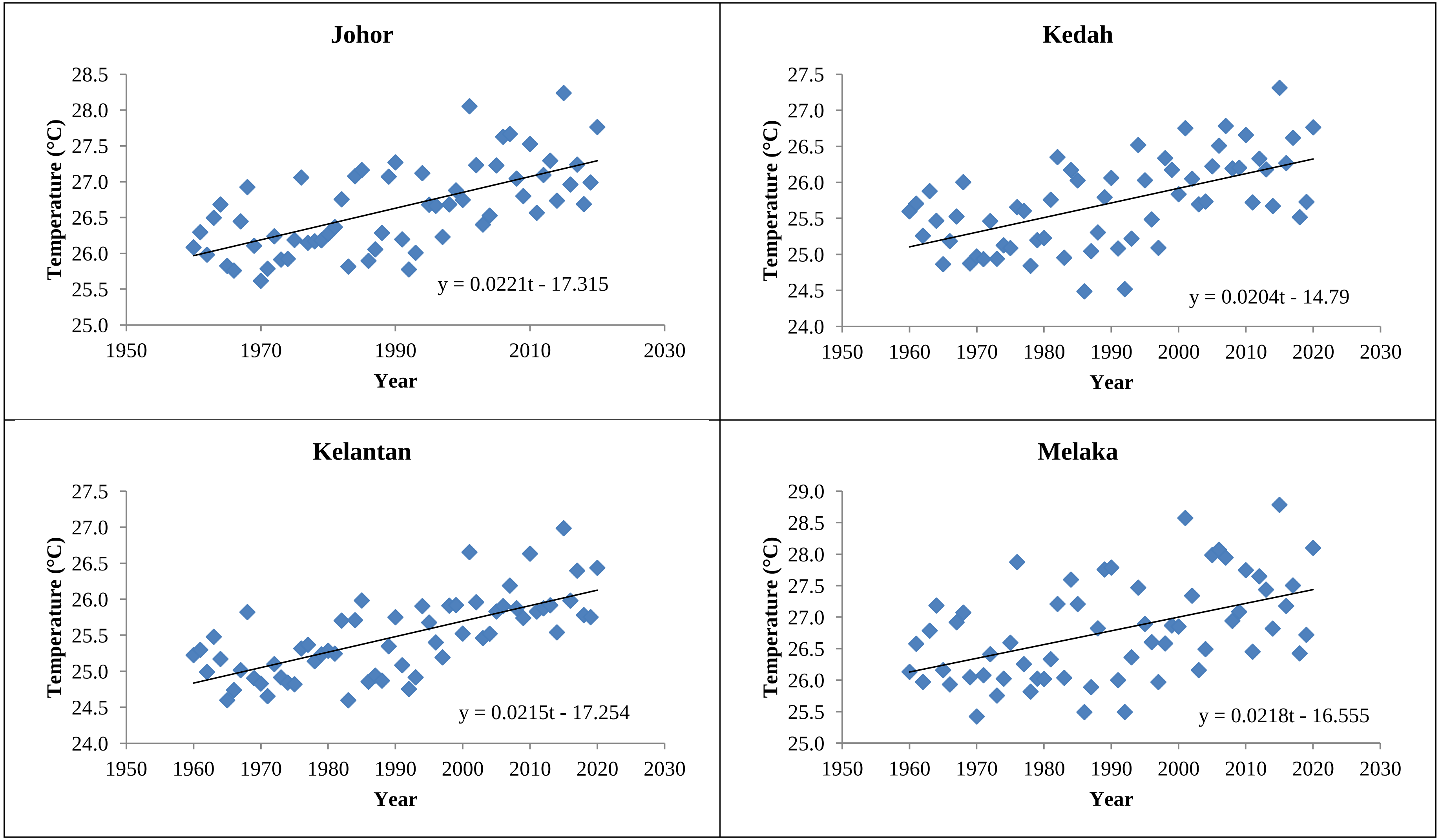


Figure 4.1 : Annual Temperature Trends for all the States from 1960 – 2020 (derived from PRECIS)

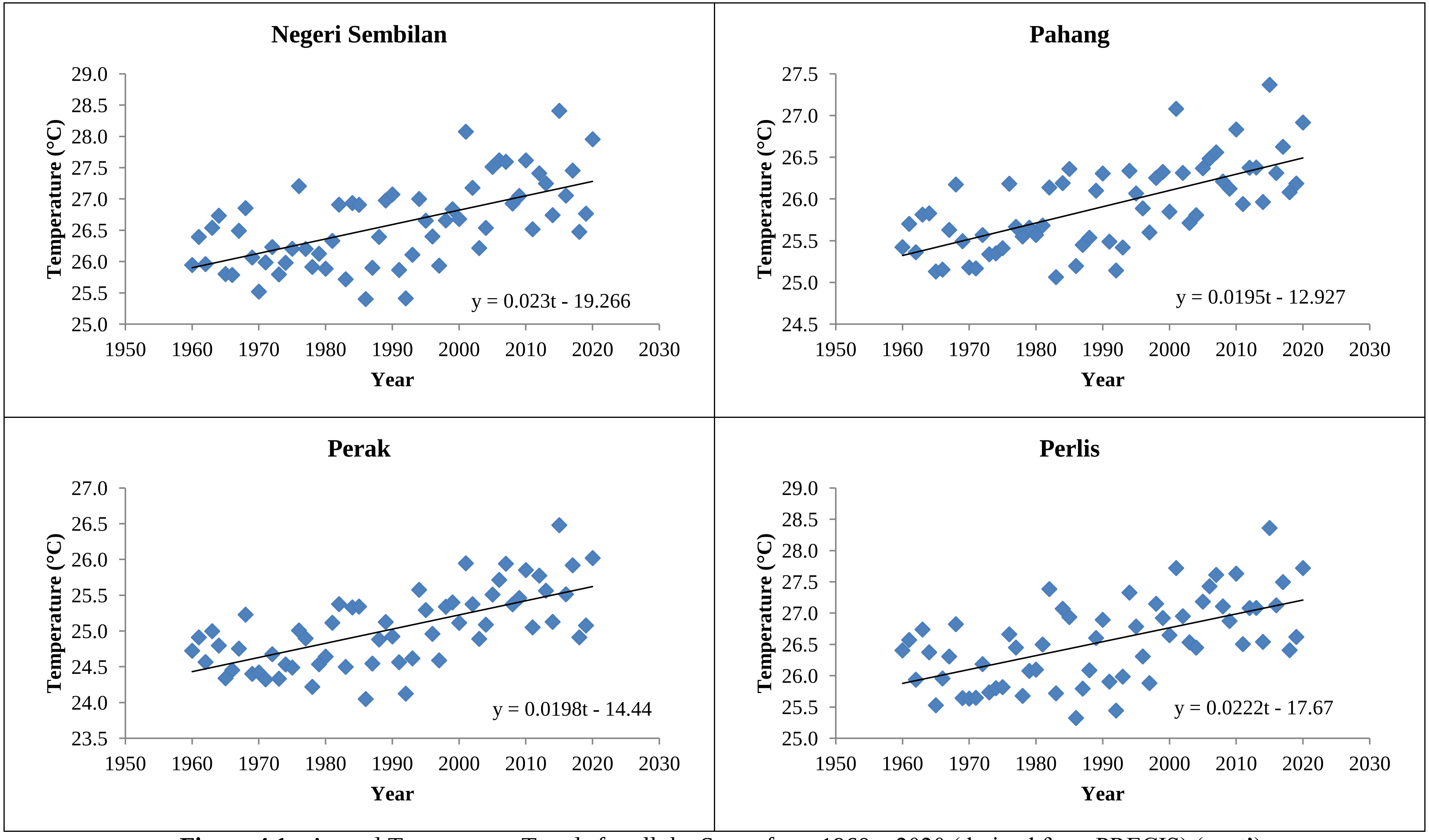


Figure 4.1 : Annual Temperature Trends for all the States from 1960 – 2020 (derived from PRECIS) (cont')

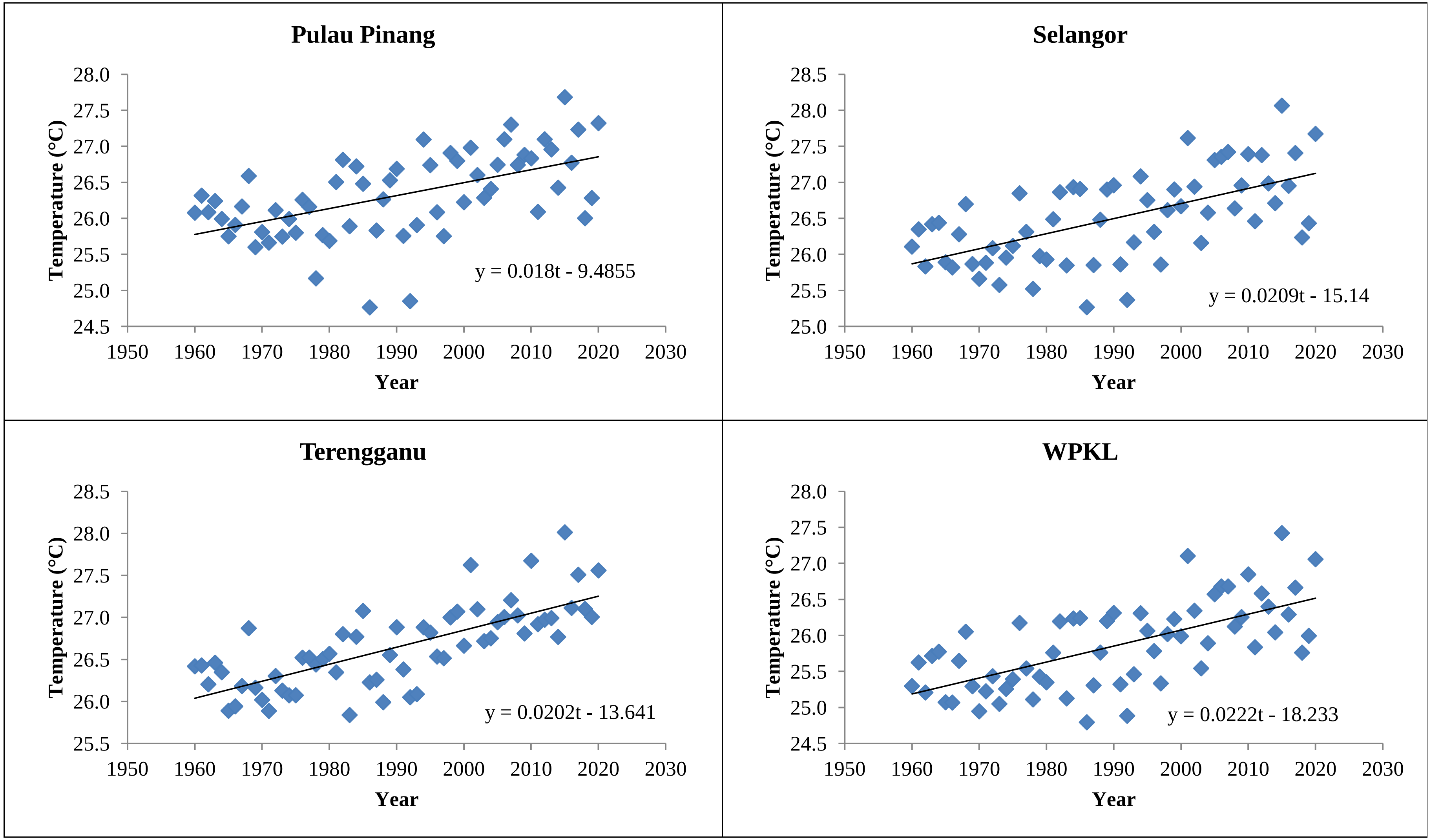


Figure 4.1: Annual Temperature Trends for all the States from 1960 – 2020 (derived from PRECIS) (cont')

After analysis and normalization of annually temperature trend for the period of 61 years (1960 – 2020), a temperature hazard map showing the temperature sub-index for Peninsular Malaysia was generated. The ranking of the state from temperature hazard consideration is presented in Table 4.1 and Figure 4.2. Pulau Pinang is the least exposure of temperature trends comparatively to other states. While, Negeri Sembilan, WPKL, Perlis, Johor and Melaka were the states to experience higher risk of temperature increased throughout the year.

Table 4.1: Temperature Risk Sub-Index

Temperature Risk Sub-Index	States (Normalized Values)
0 – 0.25	Pulau Pinang (0.0000)
0.2501 – 0.50	Pahang (0.3000), Perak (0.3600), Terengganu (0.4400), Kedah (0.4800)
0.5001 – 0.75	Selangor (0.5800), Kelantan (0.7000)
0.7501 – 1.0	Melaka (0.7600), Johor (0.8200), Perlis (0.8400), WPKL (0.8400), Negeri Sembilan (1.0000)

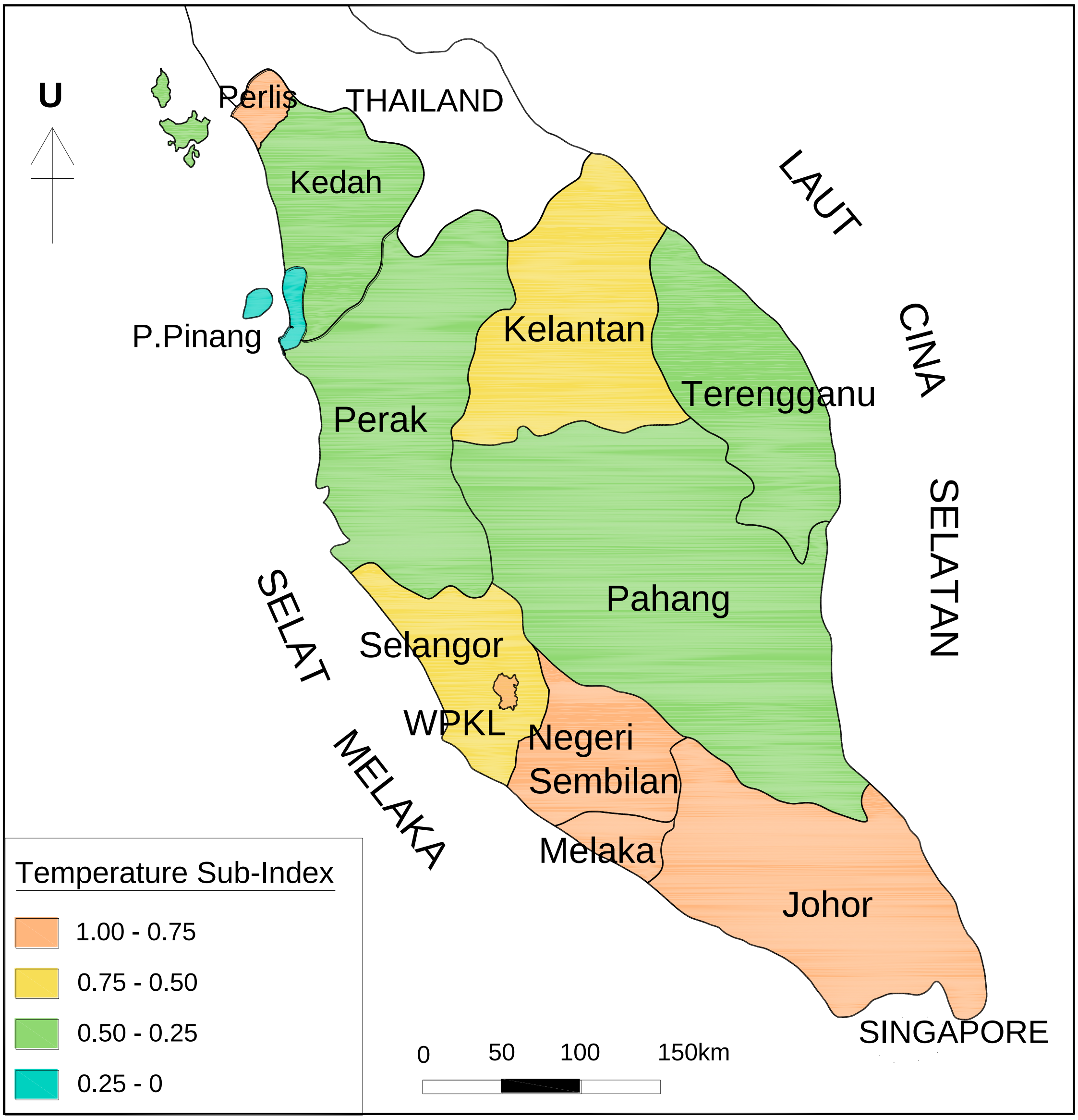


Figure 4.2: Temperature Hazard Map

4.2.2 Rainfall

The rainfall data simulated by PRECIS was gathered from 1960 to 2020. Then a linear regression was plotted with the rainfall data. The results from the trend analysis of annual total rainfall are shown in Figure 4.3. From the graphs shown in Figure 4.3, there is no uniformity in rainfall trend recorded from 1960 – 2020 for each of the state in Peninsular Malaysia. The magnitude and sign of the annual trend varies across Peninsular Malaysia. Half of the states (six out of twelve) experienced decreasing rainfall trends, while another half showed an increase in the total annual precipitation. Six states namely, Pahang, WPKL, Perak, Kelantan, Selangor and Negeri Sembilan, show a decrease trend with time for the rainfall. On the other hand, Johor was the state receiving most rainfall from 1960 to 2020. According to Wan Hassan et al. (2010), climate change can greatly influence the regional precipitation pattern. This is clearly shown in the total rainfall increased by 125.28 mm in Johor and decreased by 269.22 mm in Pahang during the period of 1960 – 2020.

In the context of floods, changes to the frequency of high intensity extreme rainfall events are more important than changes to the average rainfall. From Figure 4.3, most of the states show an increase of interval of the annual rainfall among the recent years. This situation agrees as reported in the Climate Change Scenarios for Malaysia 2001 – 2099 published by the Malaysian Meteorological Department. The report found that dry and wet years are more frequent and intense from year 1975 to 2000 compared with the period of 1951 to 1975 (Malaysian Meteorological Department, 2009). The dry and wet situation is continuous and the gap between them is more obvious, intense and magnify as projected by the PRECIS.

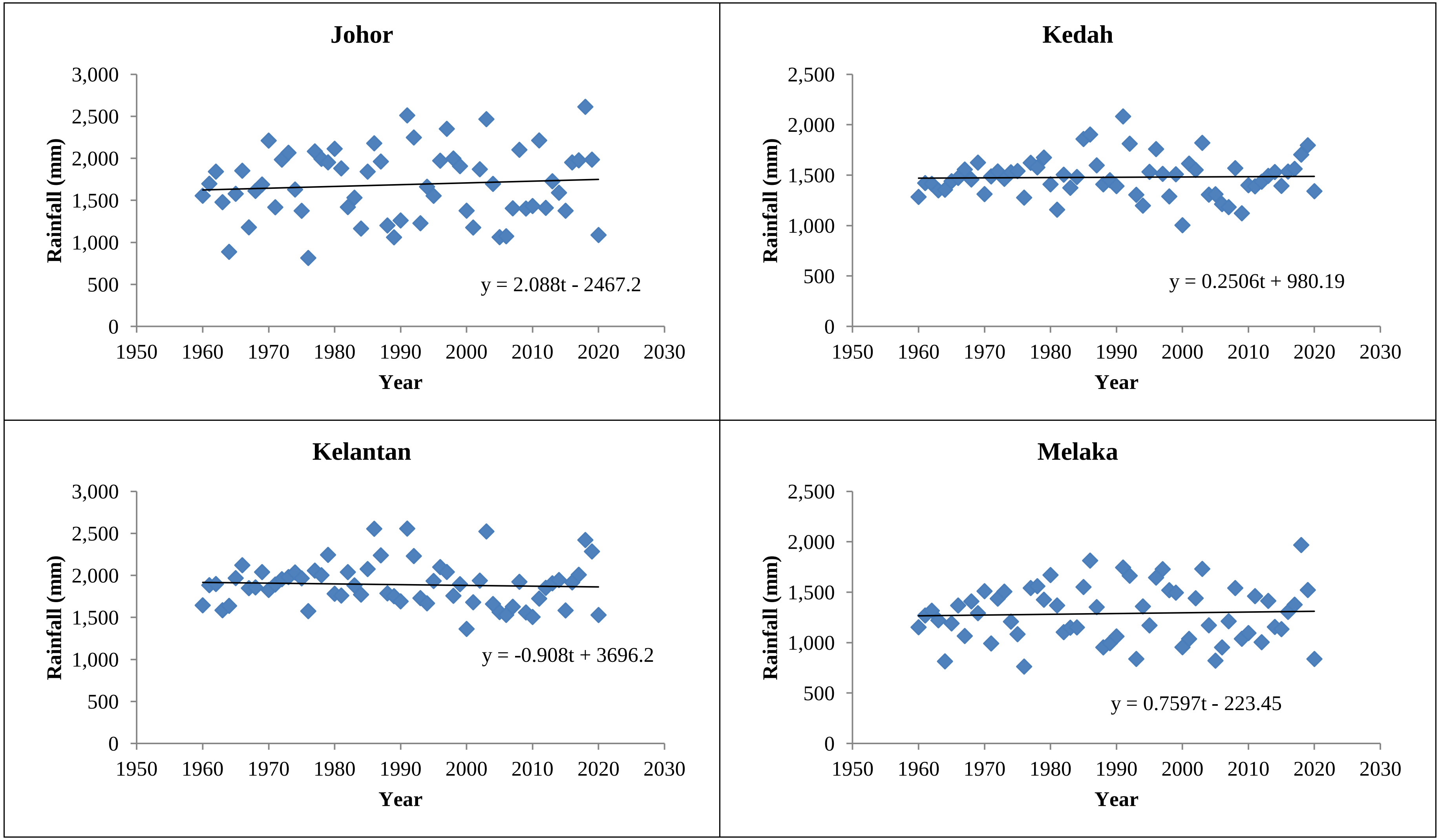


Figure 4.3: Annual Rainfall Trends for all the States from 1960 – 2020 (derived from PRECIS)

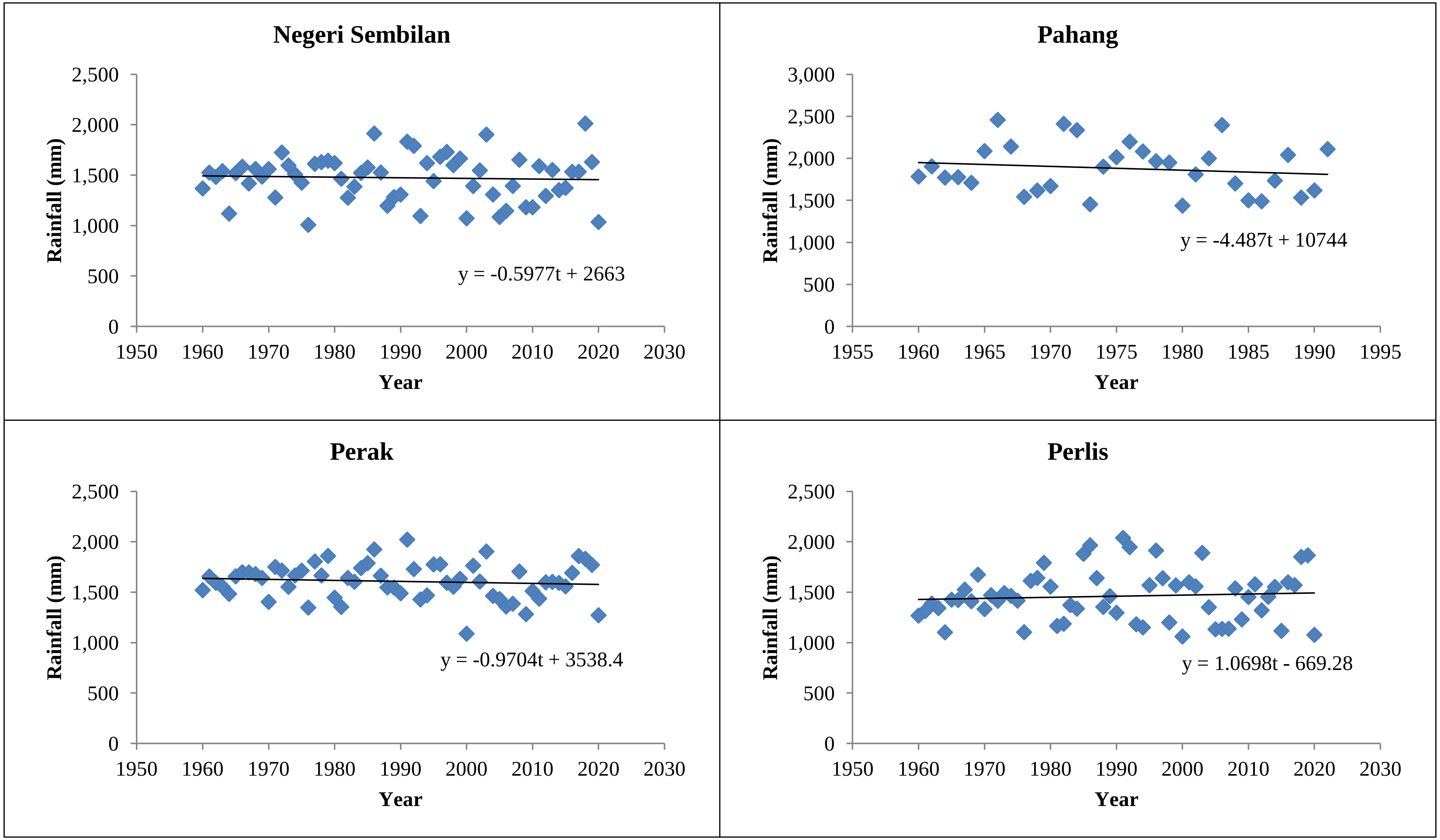


Figure 4.3: Annual Rainfall Trends for all the States from 1960 – 2020 (derived from PRECIS) (cont')

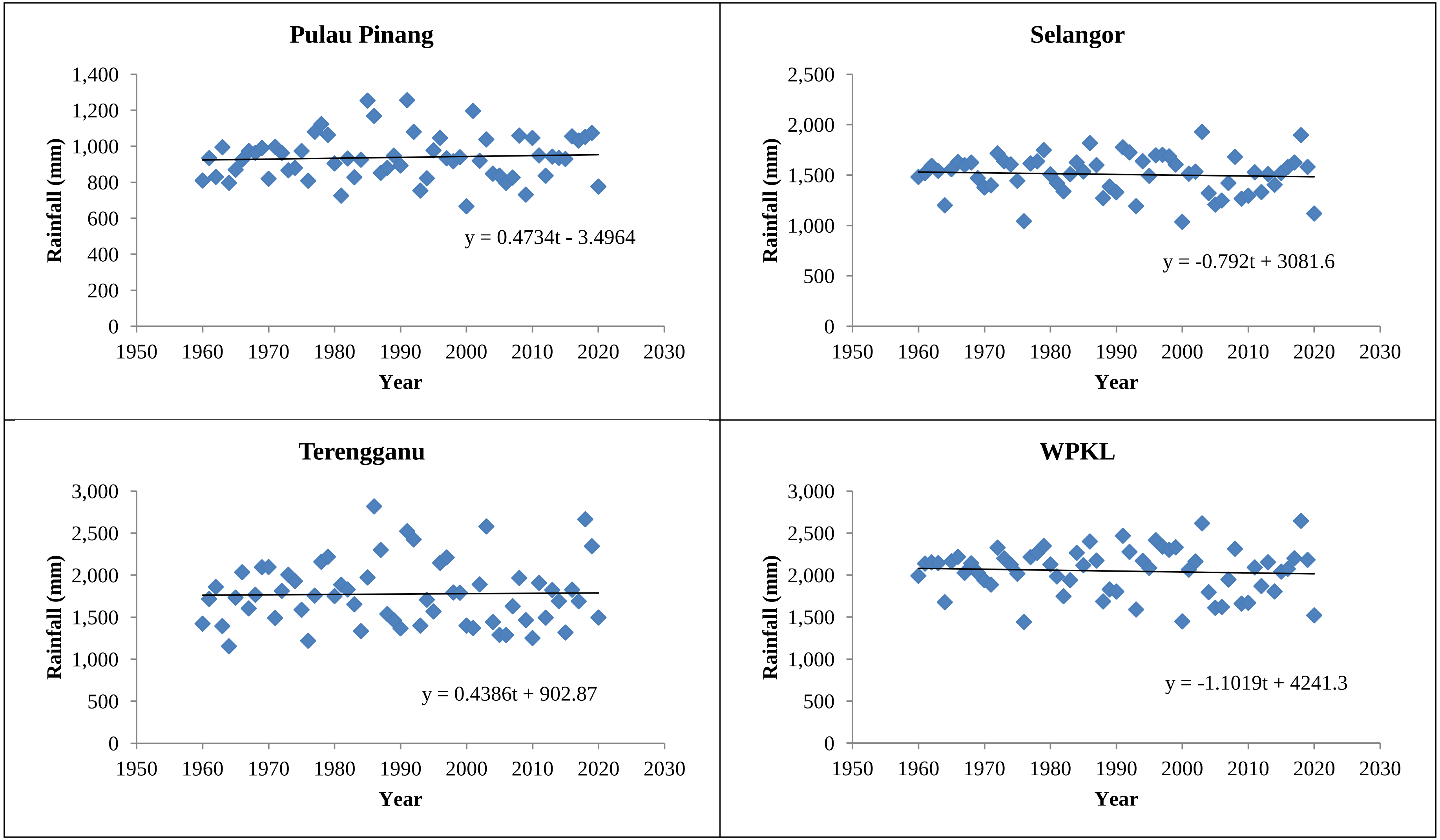


Figure 4.3: Annual Rainfall Trends for all the States from 1960 – 2020 (derived from PRECIS) (cont')

For the construction of the rainfall hazard map, the data was normalized and illustrated in Figure 4.4. The summary of rainfall risk is listed in Table 4.2. Johor had the highest rainfall sub-index which denotes Johor is highly susceptible to heavy downpour and predicted to receive more intense and frequency rainfall over time.

Table 4.2: Rainfall Risk Sub-index

Rainfall Sub-Index	States
0 – 0.25	Pahang (0.0000)
0.2501 – 0.50	-
0.5001 – 0.75	WPKL (0.5148), Perak (0.5348), Kelantan (0.5443), Selangor (0.5620), Negeri Sembilan (0.5915), Kedah (0.7205),Terengganu (0.7491)
0.7501 – 1.0	Pulau Pinang (0.7544), Melaka (0.7980), Perlis (0.0.8451), Johor (1.0000)

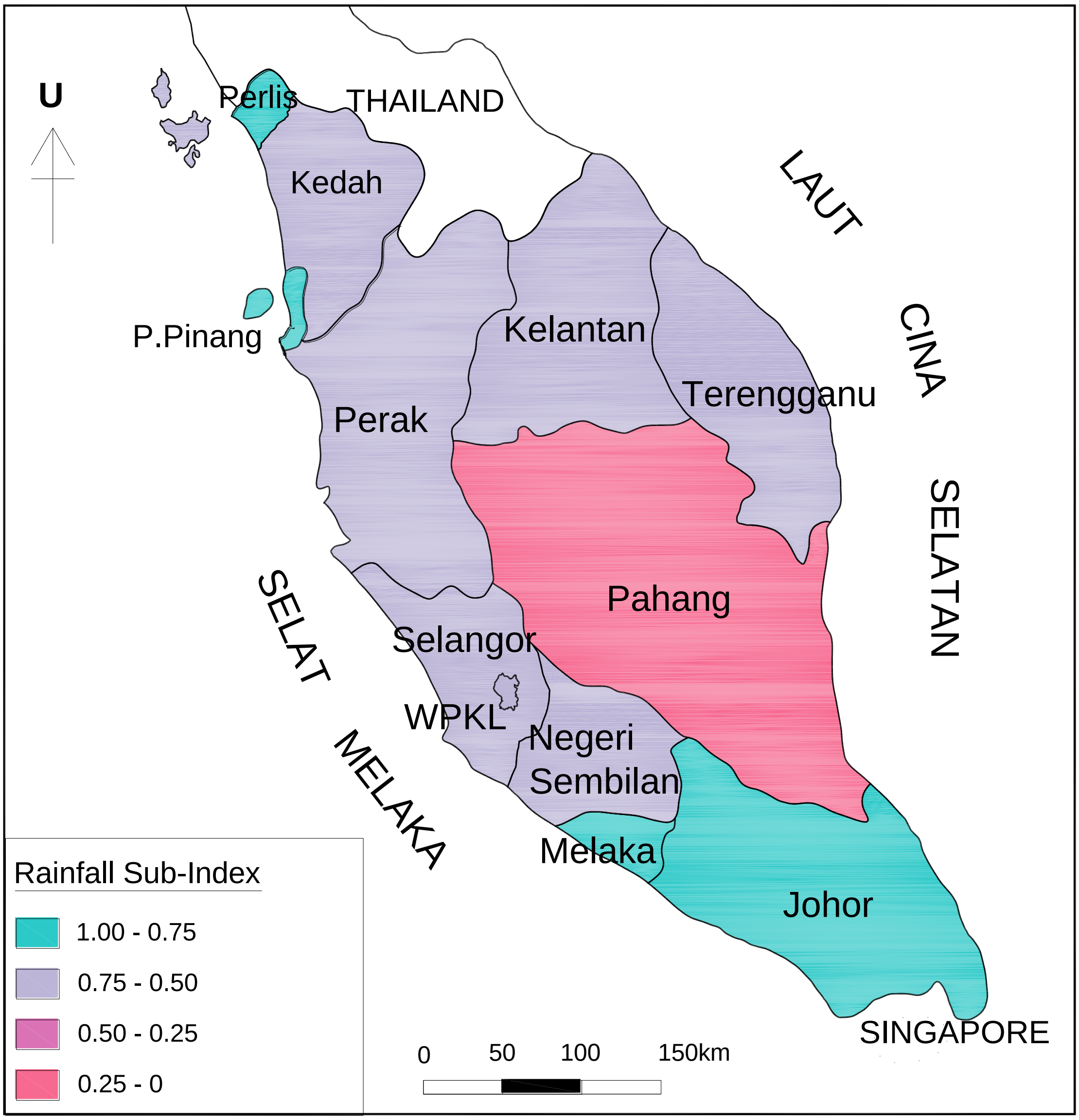


Figure 4.4: Rainfall Hazard Map

4.2.3 Flood

According to the DID Malaysia, flooding is defined as overflowing from a stream bank, lake or drainage system thus inundates the adjacent land. One of the most significant examples of weather hazard is an extreme high and low rainfall or precipitation could lead to flood and drought (DID, 2007; Zin and Jemain, 2010). Huge amount of rainfall will increased the river flow (Pan and et al., 2011). Flooding is the most significant natural hazard in Malaysia (DID, 2007). Flooding could results in severe damages and losses of properties, infrastructure and utilities, and loss of human lives especially for Peninsular Malaysia which receives an abundant amount of rainfall annually (average 2,400mm for Peninsular Malaysia). The extreme flooding episode at Johor on December 2006 and January 2007 had cost damage of RM1.5 billion in infrastructure, agriculture and properties (DID, 2007). A total of 110,000 people affected were evacuated and the death toll has reached to 18 people.

According to the research done by Pan and et al. (2011) in the Pahang River Basin, rainfall was the main climatic factor that impacts on the changes of river hydrology. Therefore, the river water level is assumed to have direct relationship with the amount of rainfall. Figure 4.5 shows the correlation between the water level (m) and the rainfall (mm). As shown in the Figure 4.5, all the states show positive relationships between the water level and the rainfall, where an increase in amount of rainfall have resulted to the increase of water level. The result showed that the rainfall has direct effect of river overflow with abundant of rainfall within a time period. This could result in flooding. Thus, rainfall is a significant factor that leads to flooding episode.

From Figure 4.5, Figure 4.6 shows the trends on water level for each of the states. Among all the states, Perlis (+0.0915m, 2.93%) is showing the most surplus in river water level from 1960 – 2020. This is follow by Pulau Pinang (+0.0305m, 1.92%), Melaka (+0.0183m, 1.87%), Johor (+0.024, 1.22%), Kedah (+0.0305m, 0.80%), and Terengganu (+0.183m, 0.25%). On the other hand, Selangor is the most critical states recorded to have deficit of 0.1525m (1.63%) of river water level during 1960 – 2020. Among other states that show deficit in river water level during the period from 1960 to 2020 are Kelantan (-0.0055m, 0.81%), WPKL (-0.061m, 0.38%), Perak (-0.0366m, 0.37%), Negeri Sembilan (-0.0122m, 0.36%), and Pahang (-0.0061m, 0.31%).

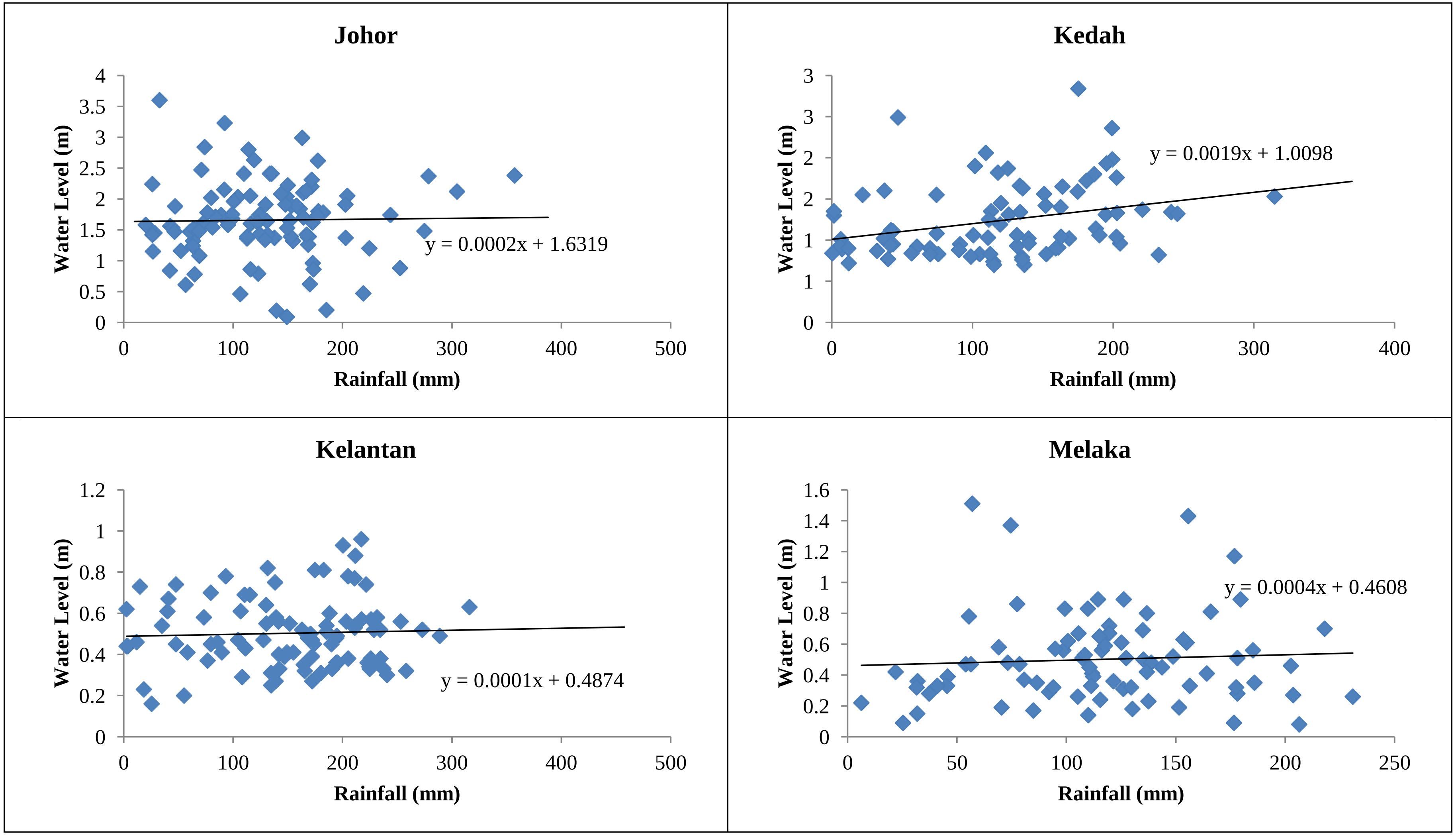


Figure 4.5: Correlation between the Rainfall (mm) and the River Water Level (m)

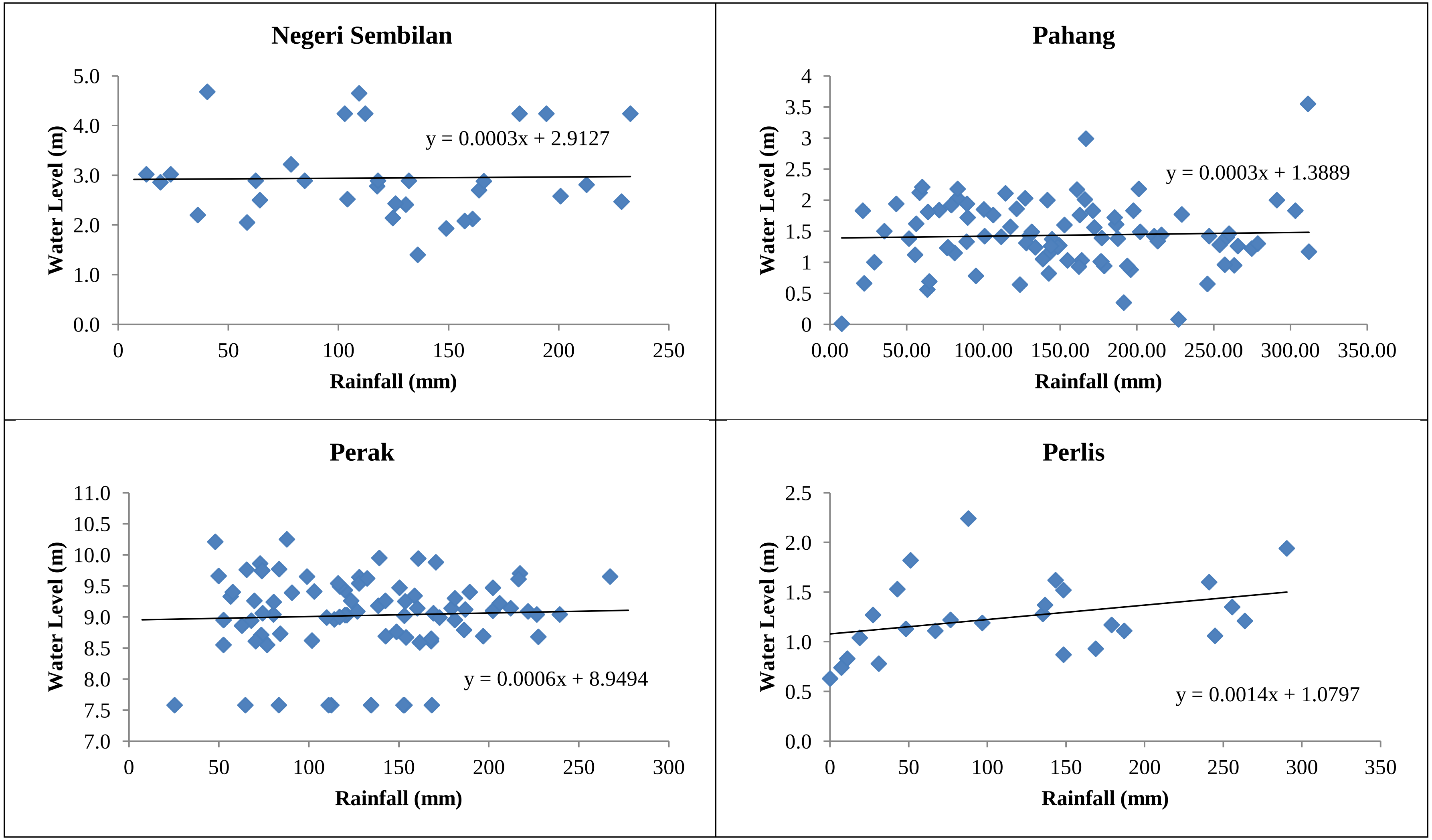


Figure 4.5: Correlation between the Rainfall (mm) and the River Water Level (m) (cont')

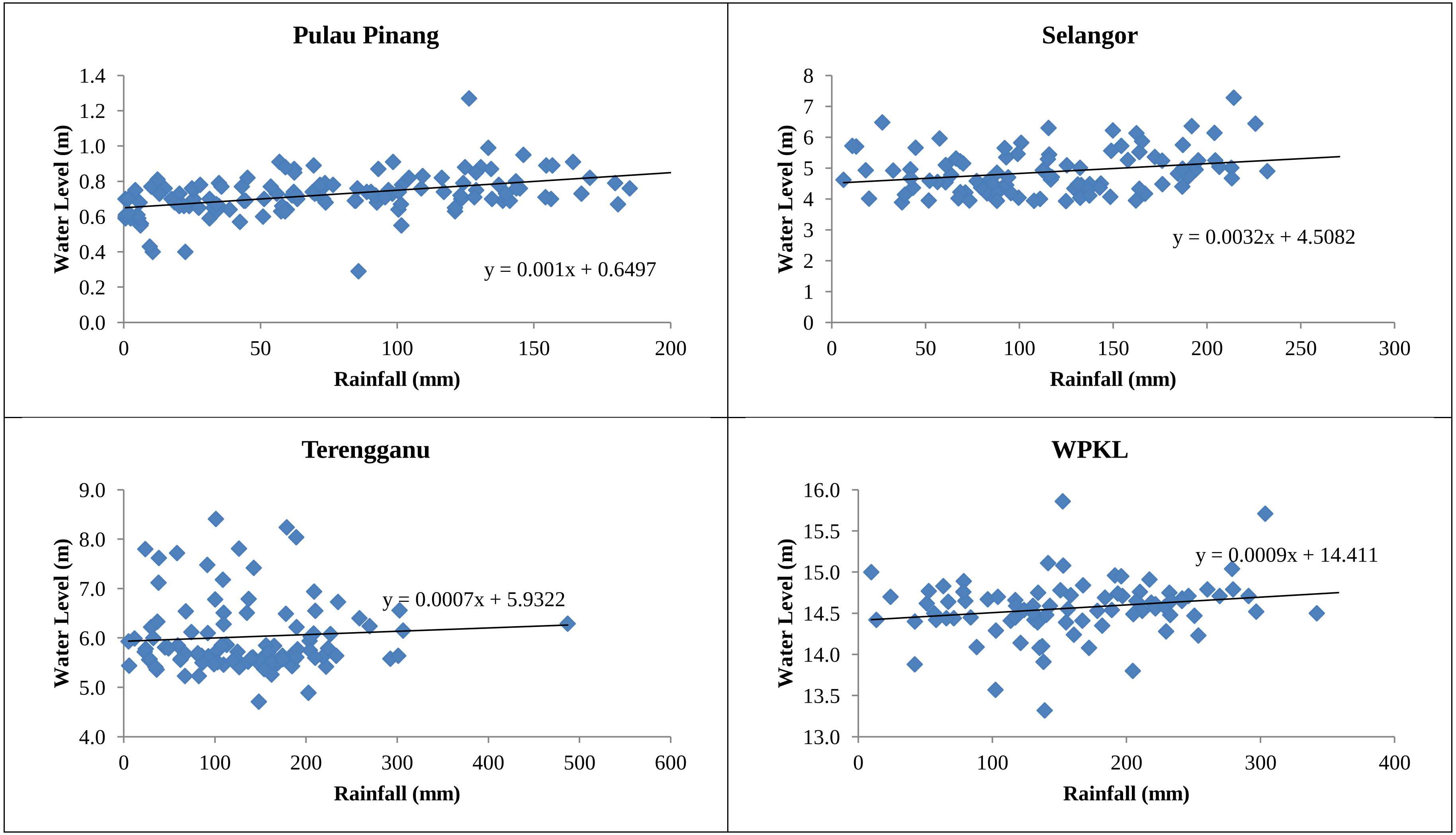


Figure 4.5: Correlation between the Rainfall (mm) and the River Water Level (m) (cont')

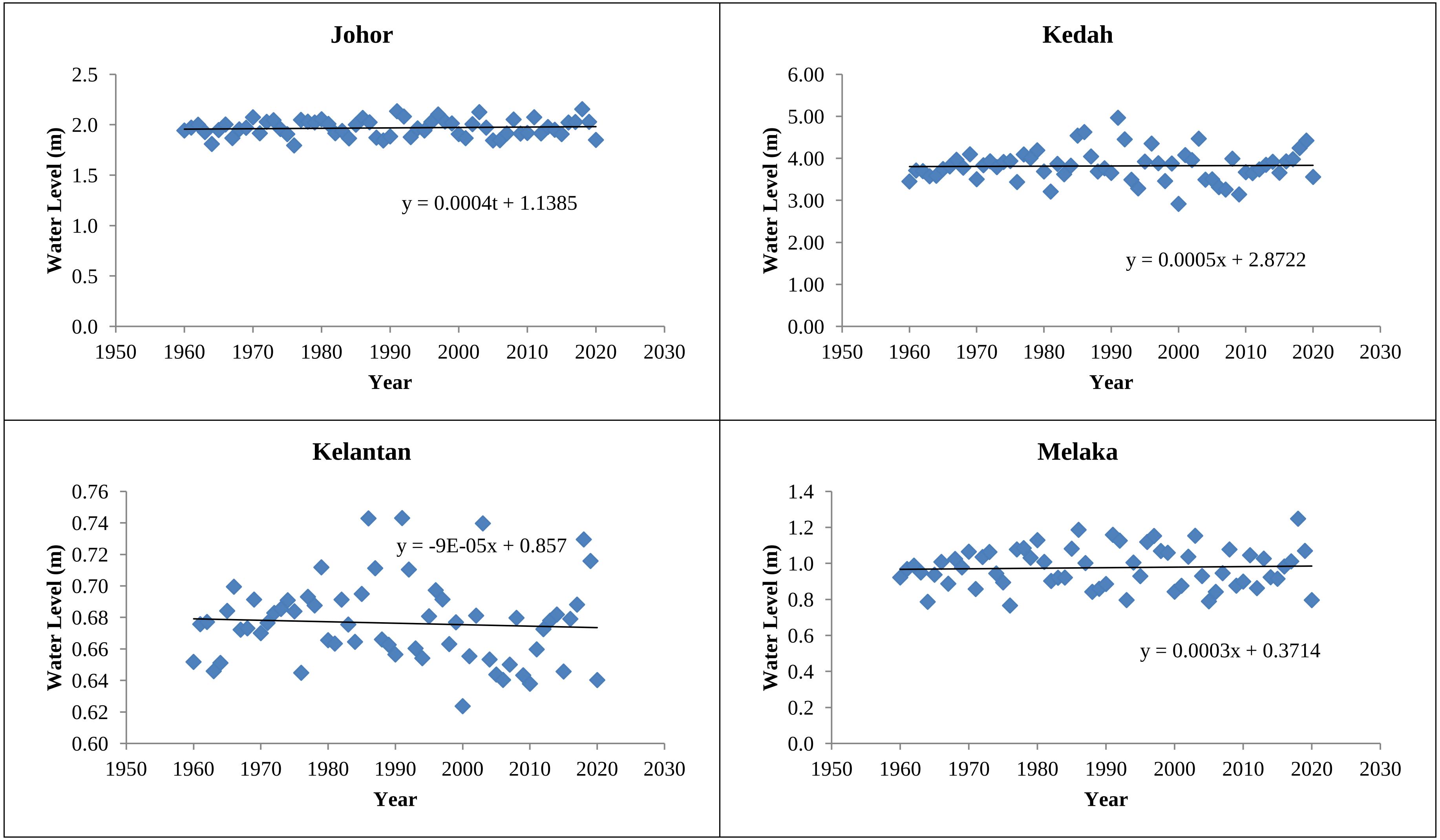


Figure 4.6: Annual River Water Level (m) Trend

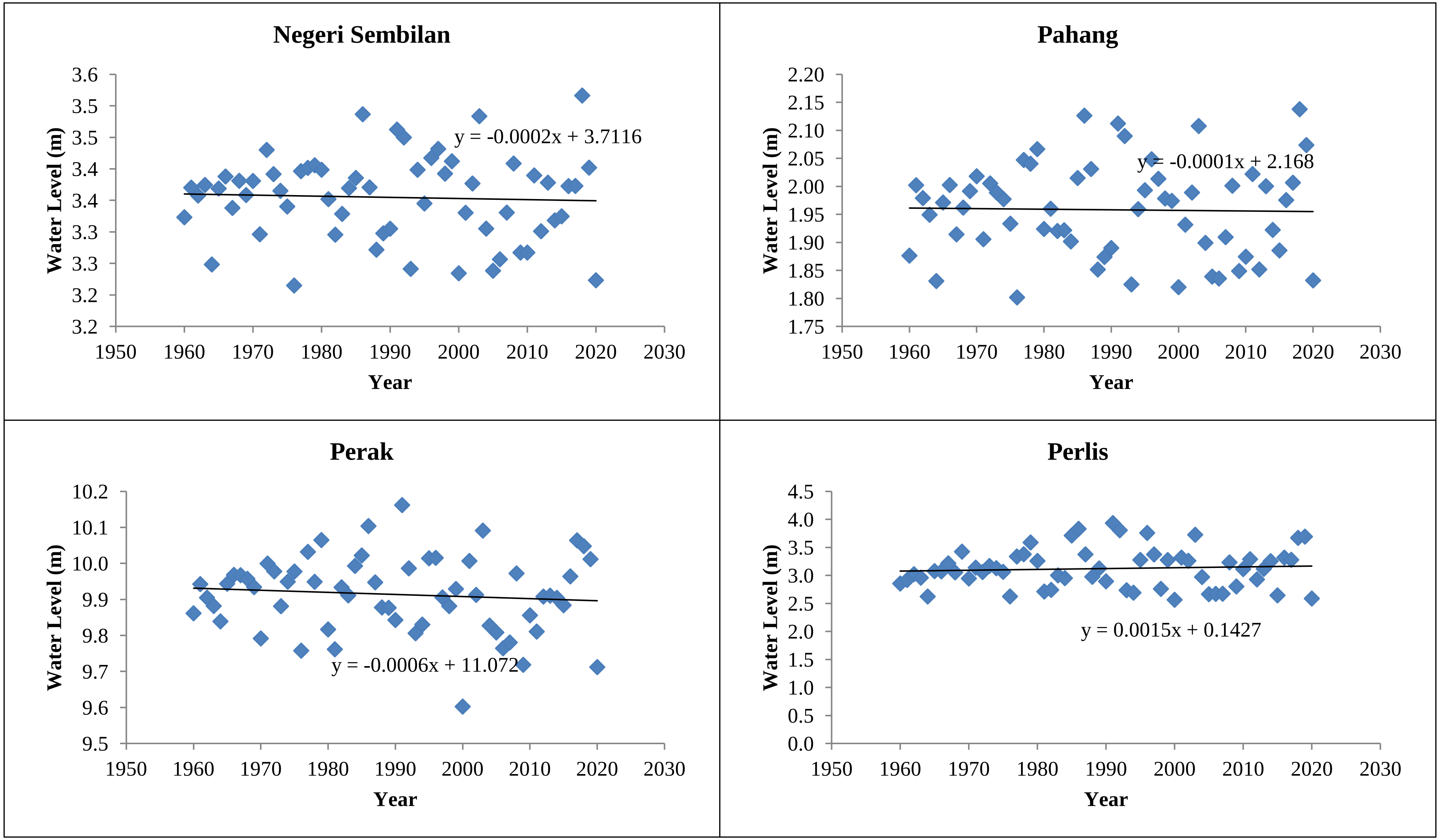


Figure 4.6: Annual River Water Level (m) Trend (cont')

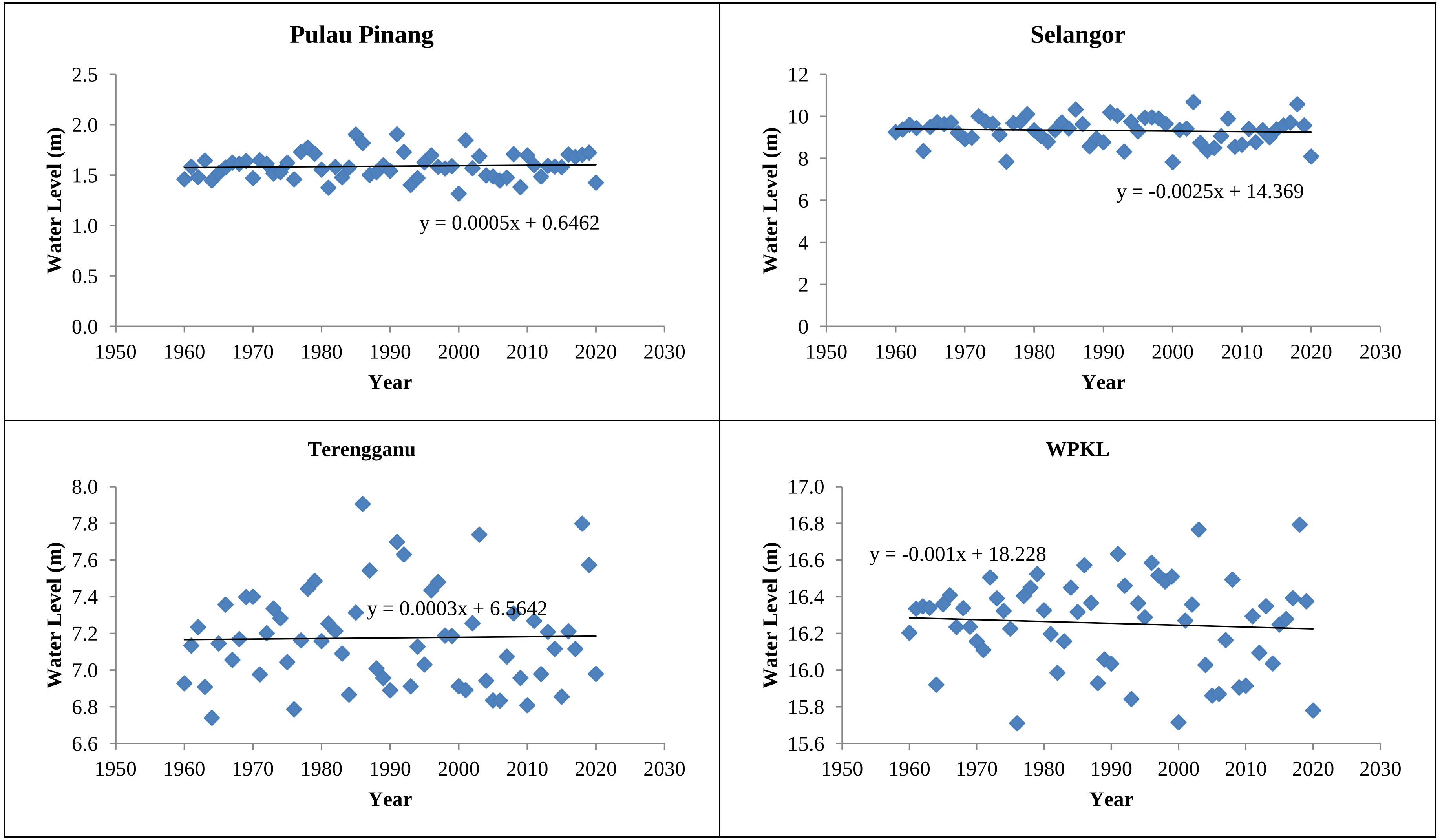


Figure 4.6: Annual River Water Level (m) Trend (cont')

Details of the flood hazard sub-index after normalization are summarized in Table 4.3 and Figure 4.7 shows the flood hazard map. Selangor has the lowest flood risk. Meanwhile, Perlis, Pulau Pinang and Melaka are more prone to flood due to climate condition. However, beside heavy downpour, flooding events are very likely to be affected by external factors as well such as human activities in the form of exploitation of natural resources and development (Pan et al., 2011).

Table 4.3: Flood Risk Sub-Index

Flood Risk Sub-Index	**States**
0 – 0.25	Selangor (0.0000), Kelantan (0.1798)
0.2501 – 0.50	WPKL (0.2741), Perak (0.2763), Negeri Sembilan (0.2785), Pahang (0.2895), Terengganu (0.4123)
0.5001 – 0.75	Kedah (0.5329), Johor (0.3250),
0.7501 – 1.0	Melaka (0.7675), Pulau Pinang (0.7785), Perlis (1.0000)

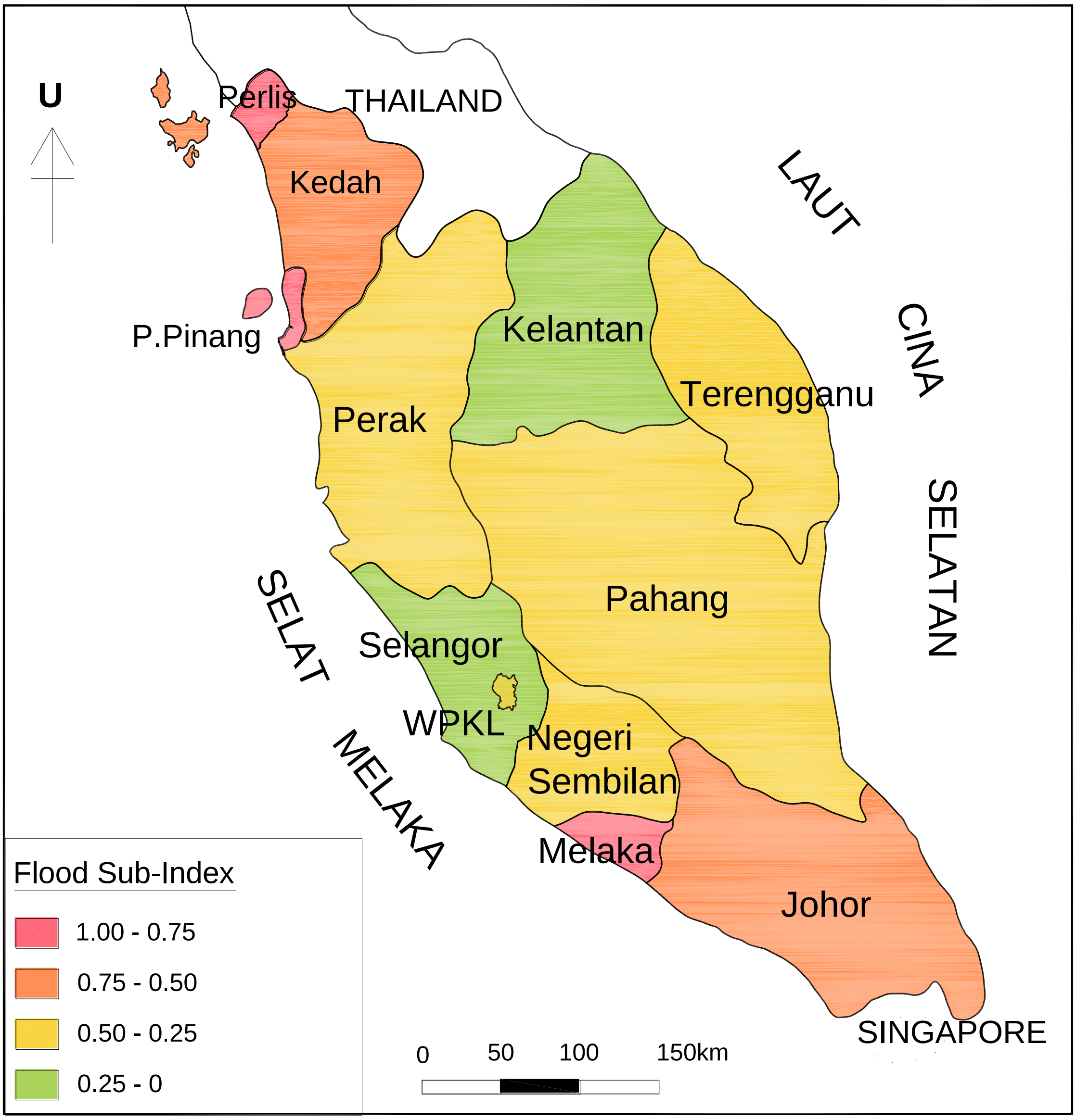


Figure 4.7: Flood Hazard Map

4.2.4 Drought

The second climate related natural hazards indicator taken into consideration in this study is drought. Drought is an occurrence of prolong dry periods (DID, 2007). Drought is occurring almost everywhere in different regions of the world with increased frequency and severity (IPCC, 2007). Malaysia receives an average of 2,500mm annually (MMD, 2012). Therefore, the chance of serious drought is very much less as compared to other countries. However, drought could lead to water resources problem since Malaysia is highly dependent on surface water sources. During the particularly dry period in 1997 – 1998, most of the water reservoirs and dams are running low. The severe drought in 1998 has affected approximately 1.8 million people in southern Kuala Lumpur, Bangi and Kajang with disrupted water supply (Shaaban & Low, 2003).

As drought can be defined as prolong duration of no rain days. Therefore, the trends in the number of days with receiving rainfall less than 0.1mm which obtained from the MMD, Malaysia for year 1983 – 2012 was plotted against the year as shown in Figure 4.8. Due to limited data for each of the states in Peninsular Malaysia, the states have been categorized as north-western, north-eastern and southern regions. North-western region consists of Perlis, Pulau Pinang, Kedah and Perlis, meanwhile north-eastern consists of Kelantan, Terengganu and Pahang. The remaining states which are Selangor, WPKL, Negeri Sembilan, Melaka and Johor are group to form southern region.

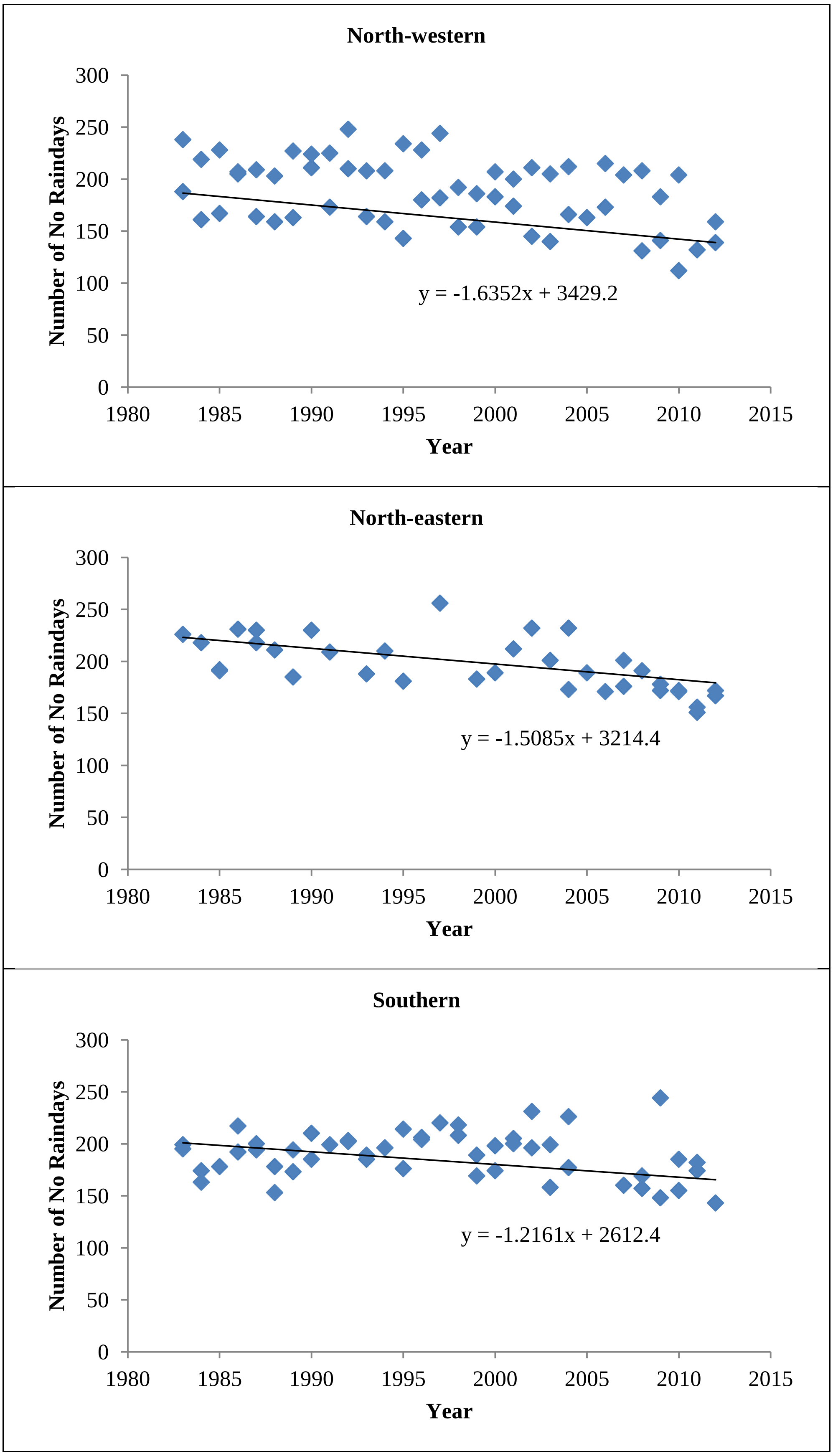


Figure 4.8: Trend of Number for No Raindays

As clearly presented in the Figure 4.8, all the states in Peninsular Malaysia are having a decline trend for number of raindays recorded from 1983 – 2012. The dry spells shown in this study seems to be in agreement with Deni et al. (2008) who reported that the trend of the number of dry days significantly decreased over the Peninsular Malaysia from 1975 – 2004. Deni et al. reported that the mean dry spells and the frequency exhibited a significant decreasing trend over peninsula Malaysia.

The trend of no raindays recorded southern region as exhibited in Figure 4.8 is parallel with the findings of Deni et al. (2008) that the southern areas tends to have higher frequency of long dry periods as compared to other regions. From the findings of Deni et al., the persistency of dry days shows a decreased trend over most of the stations in peninsular Malaysia. As conclusion, the drought indicator is negligible as a significant parameter of climate change vulnerability index in this study.

4.2.5 Mean Sea-level

Since the 20th century, mean sea-level is rising globally and it will continue to rise (Nerem & Mitchum, 2001). According to Md Din et al. (2012), global temperature change or global warming phenomenon is the main driver to mean sea-level rise. Mean sea-level rise cause bring several negative impacts to the environment such as beach erosion, inundation of small island, increase flood and storm damage, increased salinity of coastal aquifers and loss of coastal ecosystem. A study has been carried out to study the long-term sea-level change from 1983 to 2008 by Md Din in 2012. From the study, monthly mean sea-level was observed from 12 tidal stations along the coast of Peninsular Malaysia as shown in Table 4.4.

Table 4.4: Malaysian Sea-level Change from 1983 to 2008

Location of tide gauge	Tide gauge station	Linear trend (mm/yr)
West Coast	Pulau Langkawi, Kedah	1.2
	Pulau Pinang	1.8
	Lumut, Perak	2.3
	Port Klang, Selangor	2.3
	Tanjung Keling, Negeri Sembilan	1.4
	Kukup, Johor	3.0
	Johor Bahru, Johor	2.2
East Coast	Tanjung Sedili, Johor	1.8
	Pulau Tioman, Pahang	2.4
	Tanjung Gelang, Pahang	2.6
	Chendering, Terengganu	3.2
	Getting, Kelantan	1.7

Source: Md Din et al., 2012.

From the table above, natural hazard from rising mean sea-level is not considered in this study. There are several reasons to not include the mean sea-level rise into the study. Firstly, the scope of study for the climate change vulnerability mapping is assessed by state level. The average geographical elevation of the state is more emphasized rather than the solely coastal area or small island in this study. Secondly, the variance from mean sea-level rise as shown in Table 4.4 is less significant (in millimetre per year) and consistent. Therefore, the hazard from mean sea-level rise is not being weighted.

4.3 Sensitivity

4.3.1 Population Density

The population profile for each state in Peninsular Malaysia is shown in Table 4.5. According to the Department of Statistics Malaysia, the total population for Peninsular Malaysia as 2012 was 23.248 million. Selangor had the highest population (5.65 million people) among all the states in Peninsular Malaysia and Perlis recorded the lowest population of 2.394 million people. Pahang is the largest state in size with a total area of 36,137km^2 while WPKL covers the smallest area of 243km^2. On the contrary to the population distribution, the population density revealed a different scenario. Selangor being the most populous state was only ranked third in terms of population density with 694 people per square kilometre. Among the most densely populated states were WPKL (7,052 people/km^2) and Pulau Pinang (1,538 people/km^2). This was followed by Selangor (694 people/km^2), Melaka (507 people/km^2), Perlis (292 people/km^2), Kedah (211 people/km^2), Johor (180 people/km^2), Negeri Sembilan (158 people/km^2), Perak (115 people/km^2), Kelantan (109 people/km^2), and Terengganu (84 people/km^2). Finally, Pahang had the lowest population density of 43 people/km^2.

Table 4.5: Basic Demographics Characteristics by States

State	Area (km^2)	Population ('000)	Population density (per km^2)
Johor	19,210	3,439.6	180
Kedah	9,500	1,996.8	211
Kelantan	15,099	1,640.4	109
Melaka	1,664	842.5	507
Negeri Sembilan	6,686	1,056.3	158
Pahang	36,137	1,548.4	43
Perak	21,035	2,416.7	115
Perlis	821	239.4	292
Pulau Pinang	1,048	1,611.1	1,538
Selangor	8,153	5,650.8	694
Terengganu	13,035	1,092.9	84
WPKL	243	1,713.4	7,052
Malaysia	**132,631**	**23,248.3**	**176**

Source : Department of Statistics Malaysia, 2012.

Table 4.6: Population Density Risk Sub-index

Population Density Risk Sub-Index	States
0 – 0.25	Pahang (0.0000), Terengganu (0.0058), Kelantan (0.0094), Perak (0.0103), Negeri Sembilan (0.0164), Johor (0.0195), Kedah (0.0240), Perlis (0.0355), Melaka (0.0662), Selangor (0.0929), Pulau Pinang (0.2133)
0.2501 – 0.50	-
0.5001 – 0.75	-
0.7501 – 1.0	WPKL (1.0000)

For population density, WPKL is the only state within the Peninsular Malaysia which falls in highly sensitive category from Table 4.6 and Figure 4.9.

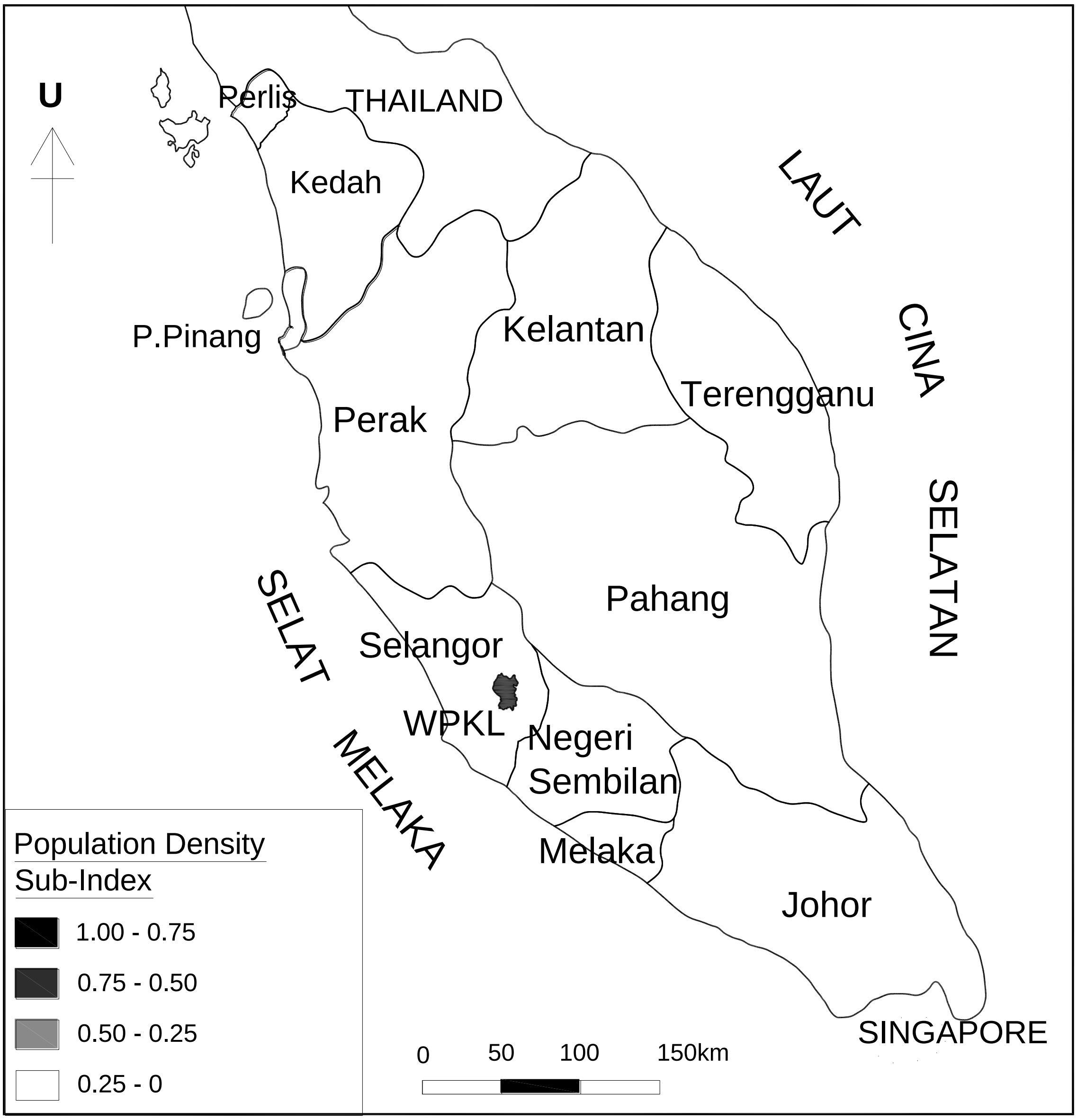


Figure 4.9: Population Density Risk Map

4.3.2 Dependency Ratio

Age distribution or composition is a critical variable in understanding population changes. For that reason, age distribution and dependency ratio by states in Peninsular Malaysia were tabulated in Table 4.7. The Department of Statistics has categorized the total population into 16 groups with 5-year intervals. The proportion of population below the age of 15 years is categorised as children, 15 to 64 years as working adults and above 65 years as elderly. The dependency ratio is the percentage of those who are not economically active and therefore dependent over those who are economically active. WPKL had the lowest dependency ratio of 0.2435 amongst the states. The dependency ratio was similar for Selangor (0.2873). A few states showed that the proportion of the dependent groups (below 15 years and above 65 years) is more than the independent group (15 to 64 years). These are Kelantan (0.6114), Kedah (0.5505) and Perak (0.5238). The proportion of population is almost equal for other non-mentioned states.

Table 4.7: Dependency Ratio by States in the Peninsular Malaysia

State	Children (Age 0-14)	Adult (Age 15-64)	Elderly (Age 65+)	Dependency Ratio
Johor	910,413	2,259,865	178,005	0.4816
Kedah	571,559	1,256,117	119,975	0.5505
Kelantan	497,464	955,459	86,678	0.6114
Melaka	215,670	554,657	50,783	0.4804
Negeri Sembilan	271,214	691,427	58,423	0.4767
Pahang	452,801	1,048,016	29,166	0.4599
Perak	626,615	1,544,001	182,127	0.5238
Perlis	58,435	156,240	16,866	0.4820
Pulau Pinang	361,081	1,099,641	100,661	0.4199
Selangor	1,372,012	3,893,003	197,126	0.2873
Terengganu	334,533	950,849	50,595	0.4050
WPKL	307,204	1,588,696	79,721	0.2435

Source: Department of Statistics Malaysia, 2011.

Table 4.8: Dependency Ratio Risk Sub-Index

Dependency Ratio Risk Sub-Index	States
0 – 0.25	WPKL (0.0000), Selangor (0.1191)
0.2501 – 0.50	Terengganu (0.4390), Pulau Pinang (0.4795)
0.5001 – 0.75	Pahang (0.5882), Melaka (0.6439), Johor (0.6472), Perlis (0.6483), Negeri Sembilan (0.6882)
0.7501 – 1.0	Perak (0.7619), Kedah (0.0.8345), Kelantan (1.0000)

As seen from Figure 4.10 and Table 4.8, Kelantan, Kedah and Perak had the highest risk in terms of their dependency ratio. On the contrary, Selangor and WPKL had the lowest risk.

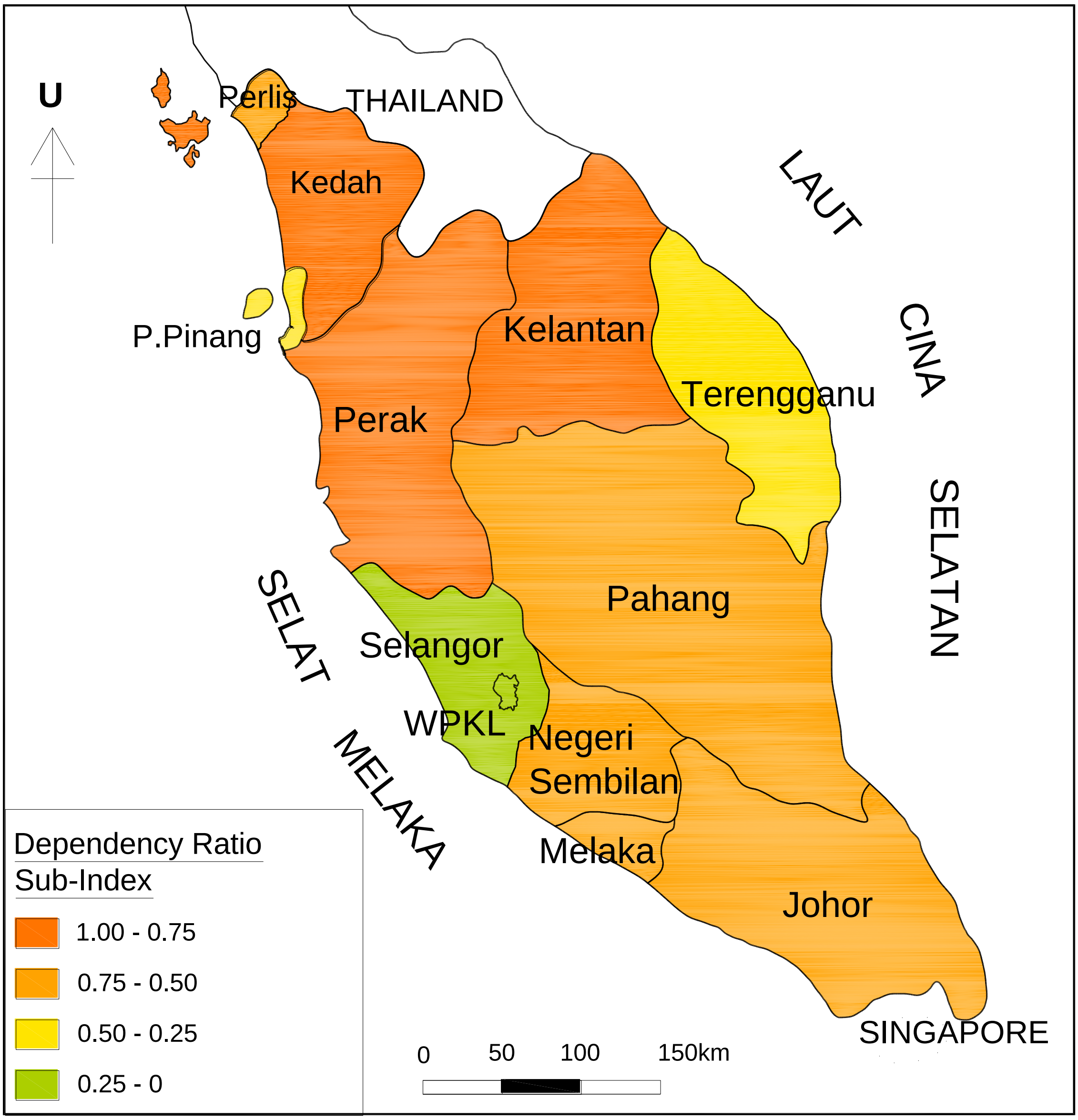


Figure 4.10: Dependency Ratio Risk Map

4.3.3 Health Facilities

The health indicator used in this study is the number of beds available in the government, semi-private and private hospitals per 100,000 populations. Selangor (9,229) recorded the most number of hospital beds among all the states. However, Perlis only recorded 406 of hospital beds in year 2012 as shown in Table 4.9.

Table 4.9: Health Facilities in Peninsular Malaysia

State	No. of bed	Population ('000)	No of bed/1,000 people
Johor	6,051	3,269.1	1.8510
Kedah	2,787	1,942.6	1.4347
Kelantan	1,825	1,639.0	1.1135
Melaka	1,969	761.6	2.5853
Negeri Sembilan	1,966	1,000.3	1.9654
Pahang	2,120	1,516.7	1.3978
Perak	6,723	2,427.6	2.7694
Perlis	406	237.0	1.7131
Pulau Pinang	4,730	1,580.0	2.9937
Selangor	9,229	5,033.5	1.8335
Terengganu	1,403	1,035.8	1.3545
WPKL	6,876	1,703.1	4.0373

Source: Ministry of Health Malaysia, 2013.

After normalization as shown in Table 4.10 and Figure 4.11 show that WPKL is the well-equipped with health facilities in terms of bed availability in government and private hospitals compared to other states because WPKL has the most populated population.

Table 4.10 : Health Facilities Risk Sub-Index

Sub--Index	States
0 – 0.25	WPKL (0.0000)
0.2501 – 0.50	Pulau Pinang (0.3569), Perak (0.4336), Melaka (4966)
0.5001 – 0.75	Negeri Sembilan (0.7086), Johor (0.7478)
0.7501 – 1.0	Selangor (0.7537), Perlis (0.7949), Kedah (0.8901), Pahang (0.9028), Terengganu (0.9176), Kelantan (1.0000)

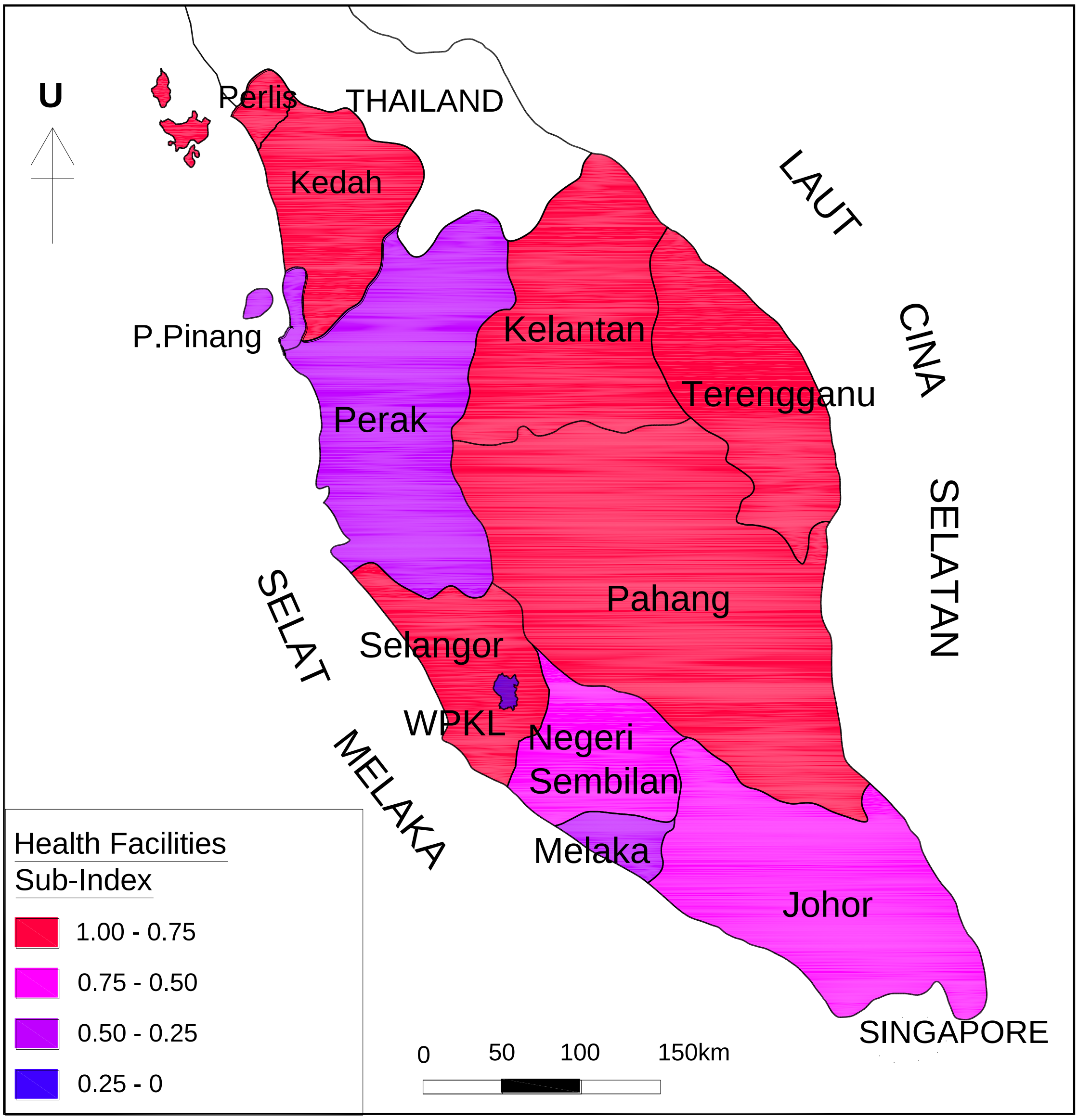


Figure 4.11: Health Facilities Risk Map

4.3.4 Poverty

The Poverty Line Income (PLI) is an indicator derived from the Household Survey Report (HIS) for gauging the incidence of poverty. Incidence of poverty is the proportion of families with the per capita incomes below the poverty threshold. Table 4.11 shows the poverty incidence according to the states in the Peninsular Malaysia for year 2010. Perlis (6.0%) posted as the highest poverty incidence in 2012. This means approximately 6.0% of people in this population had an income below the poverty level, as defined by the Government. This was followed by Kedah (5.3%), Kelantan (4.8%), Terengganu (4%) and Perak (3.5%). On the contrary, Melaka (0.5), Negeri Sembilan (0.7), Selangor (0.7) and WPKL (0.7) posted the lowest poverty incidence rate.

Table 4.11: Incidence of Poverty (%) by States in the Peninsular Malaysia

State	Incidence of Poverty (%)
Johor	1.3
Kedah	5.3
Kelantan	4.8
Melaka	0.5
Negeri Sembilan	0.7
Pahang	2.1
Perak	3.5
Perlis	6.0
Pulau Pinang	1.2
Selangor	0.7
Terengganu	4.0
WPKL	0.7

Source: Economic Planning Unit, 2013.

Table 4.12: Incidence of Poverty Risk Sub-Index

Incidence of Poverty Risk Sub-Index	States
0 – 0.25	Melaka (0.0000), Selangor (0.0364), WPKL (0.0364), Negeri Sembilan (0.0364), Pulau Pinang (0.1273), Johor (0.1455)
0.2501 – 0.50	Pahang (0.2909)
0.5001 – 0.75	Perak (0.5455), Terengganu (0.6364)
0.7501 – 1.0	Kelantan (0.7818), Kedah (0.8727), Perlis (1.0000)

From Table 4.12 and Figure 4.12, Perlis, Kedah and Kelantan were the states which had the highest incidence of poverty after normalization. In contrast, Melaka, Selangor, WPKL, Negeri Sembilan, Pulau Pinang, and Johor faced the lowest risk result from poverty.

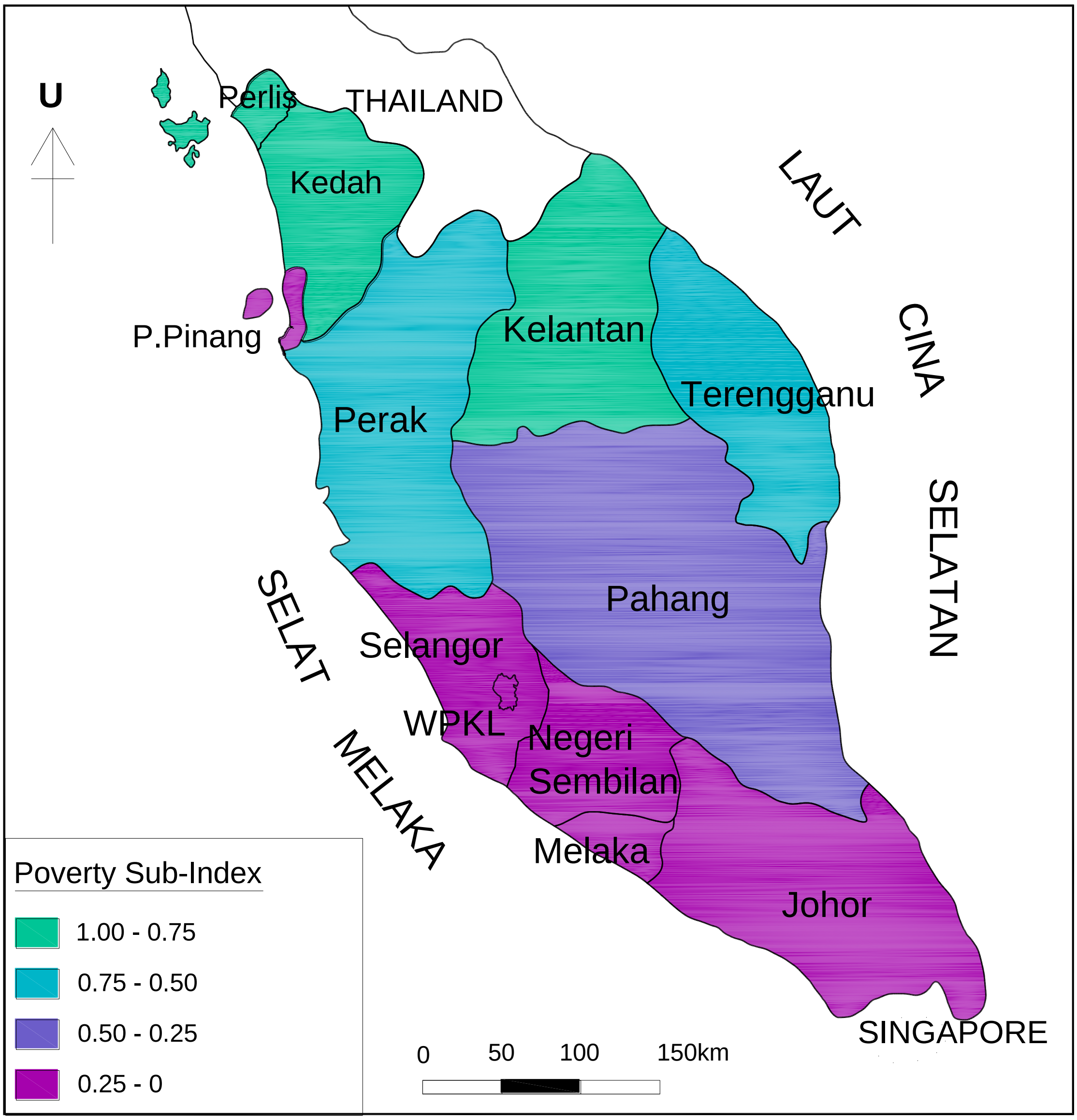


Figure 4.12: Incidence of Poverty Risk Map

4.3.5 Gross Domestic Products

Gross Domestic Product (GDP) per capita is often used as an indicator of the standard of living in an economy and commonly used as a benchmark for measuring a nation's economic progress. Table 4.13 shows the GDP per capita for year 2010. A higher GDP per capita illustrates a better standard of living of individual members of the population. WPKL showed the highest GDP per capita of RM55,951. This means on average the income of each individual in WPKL is approximately RM55, 951 per annum. On the other hand, Kelantan only generated RM8, 273 per annum. This indicates that Kelantan is the poorest state and is having huge difference in standard of living compared with other states within Peninsular Malaysia.

Table 4.13: Gross Domestic Product (GDP) per Capita by State for 2010 at Current Price (RM)

State	GDP per Capita (RM)
Johor	20,911
Kedah	13,294
Kelantan	8,273
Melaka	24,697
Negeri Sembilan	27,485
Pahang	22,743
Perak	16,088
Perlis	15,296
Pulau Pinang	33,456
Selangor	31,363
Terengganu	19,225
WPKL	55,951

Source: Department of Statistics, 2012.

Table 4.14: Gross Domestic Product Risk Sub-Index

GDP Risk Sub-Index	States
0 – 0.25	WPKL (0.0000)
0.2501 – 0.50	Pulau Pinang (0.4718)
0.5001 – 0.75	Selangor (0.5157), Negeri Sembilan (0.5970), Melaka (0.6555), Pahang, Johor (0.7349)
0.7501 – 1.0	Terengganu (0.7703), Perak (0.8361), Perlis (0.8527), Kedah (0.8942), Kelantan (1.0000)

The GDP Risk Sub-Index is tabulated in Table 4.14 and illustrated in Figure 4.13. WPKL was the only state which fell under the low risk category, followed by Pulau Pinang. It is clearly shown that the northern states of Peninsular Malaysia fall under the high risk category except for Pulau Pinang.

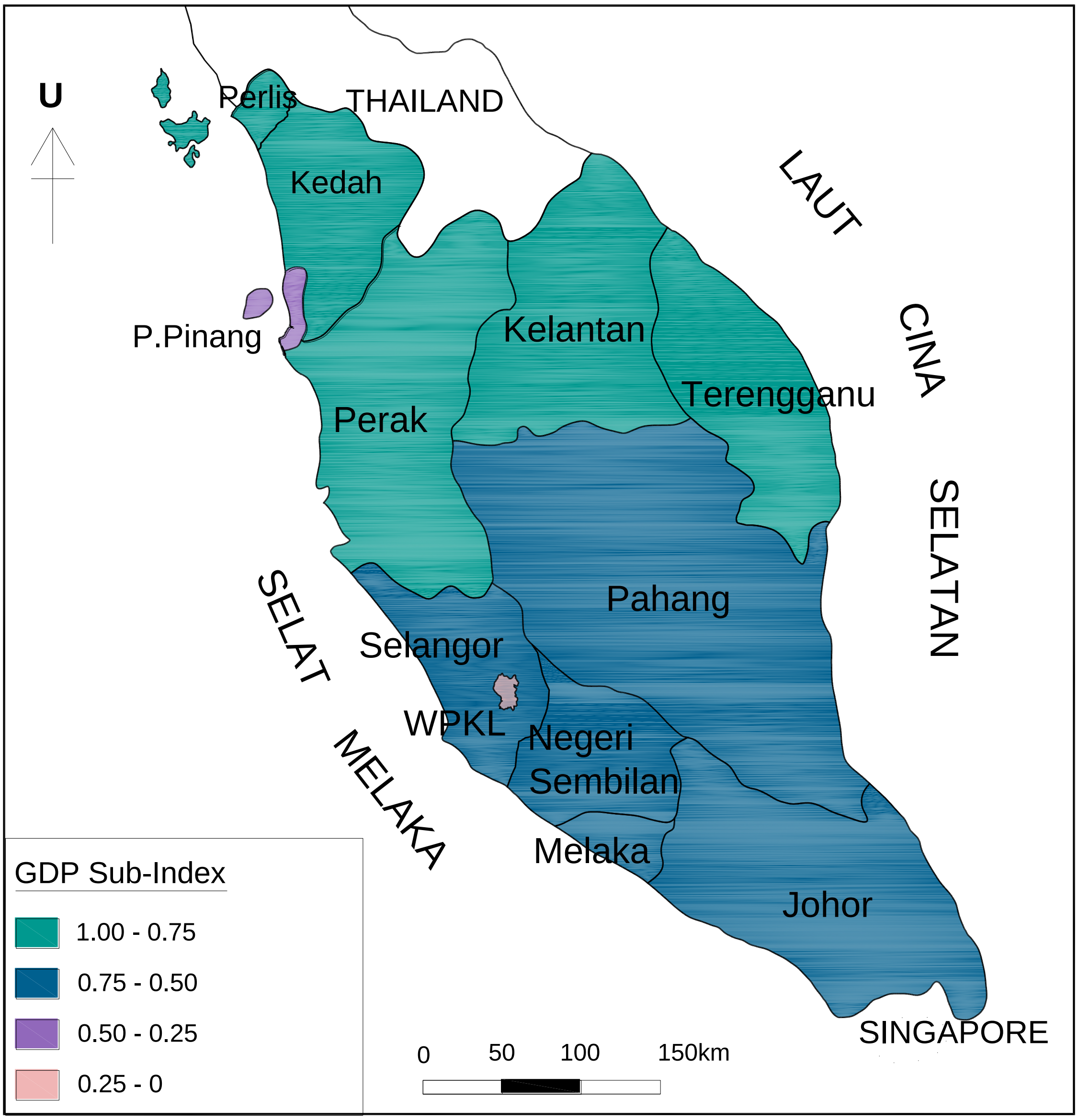


Figure 4.13: Gross Domestic Product (GDP) Risk Map

4.3.6 Air Quality

Since the Industrial Era and introduction of fossil fuel consumption, ambient air quality has deteriorated and air pollution has become a threat to the environment and human health. Hence, a continuous air quality monitoring network was established by the Department of Environment Malaysia to detect any significant change in the air quality which may be harmful to human health and the environment. The states within Peninsular Malaysia have been grouped into 3 different regions, namely north-western, north-eastern and southern regions. North-western region comprises Perlis, Pulau

Pinang, Kedah and Perlis, meanwhile north-eastern comprises Kelantan, Terengganu and Pahang. Selangor, WPKL, Negeri Sembilan, Melaka and Johor are the southern region. Presented in Figure 4.14, north-western and southern regions show positive correlation trend, an increase number of good API days. On the other hand, north-eastern region namely, Kelantan, Terengganu and Pahang recorded to have decreased in number of good API days.

Table 4.15 and Figure 4.15 show the air pollution risk sub-index. North-eastern Region was the high risk states which face severe air quality deterioration resulting from climate change. However, beside the source of pollution, ambient air quality is also affected several factors such as topography, meteorology, the physical and chemical properties of pollutants.

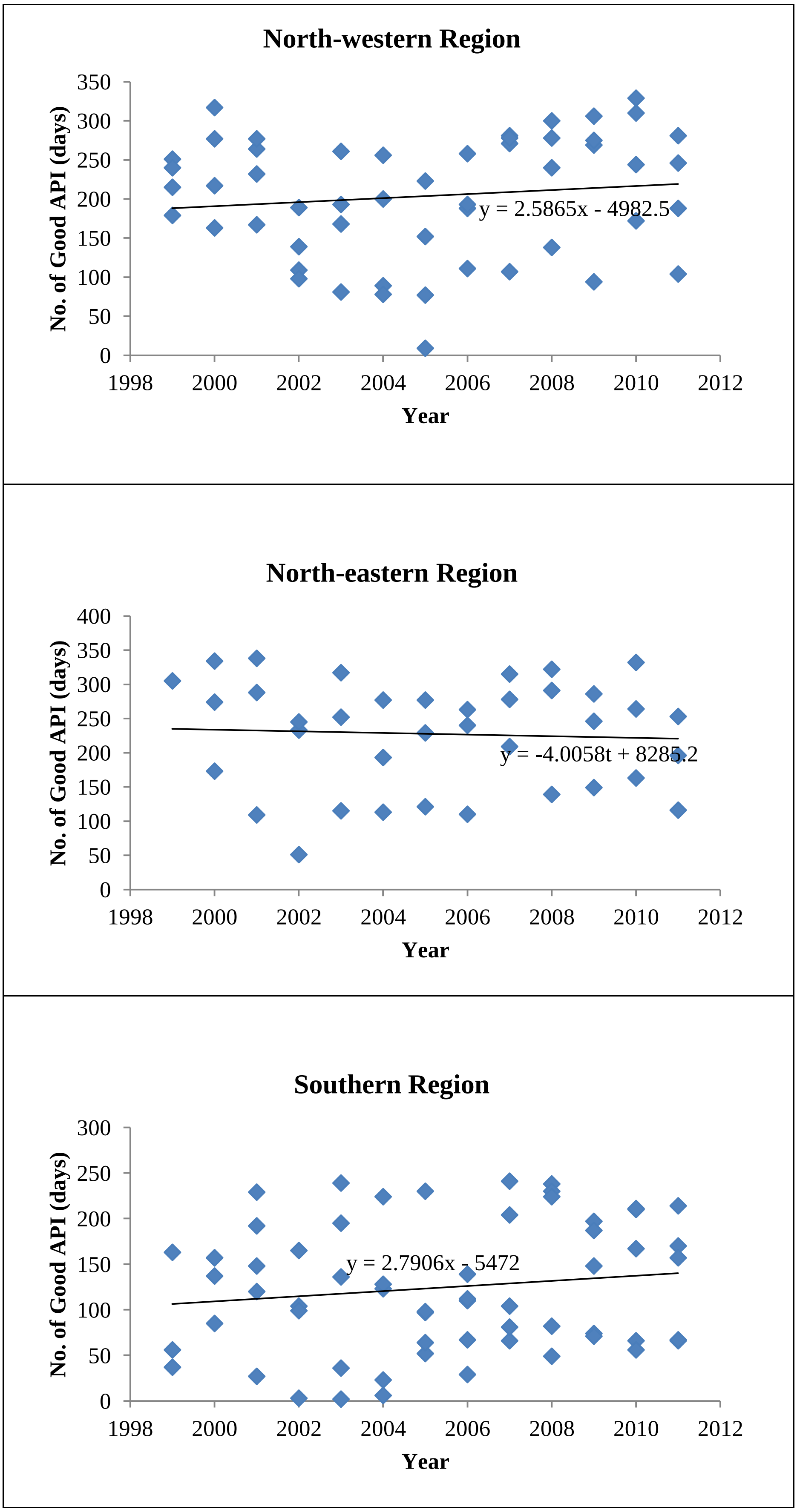


Figure 4.14: Trend for Number of Good API days

Table 4.15 Air Pollution Risk Sub-Index

Air Pollution Risk Sub-Index	States
0 – 0.25	Southern Region - Selangor, WPKL, Negeri Sembilan, Melaka and Johor (0.0000) North-west Region - Perlis, Pulau Pinang, Kedah and Perlis (0.0300)
0.2501 – 0.50	-
0.5001 – 0.75	-
0.7501 – 1.0	North-eastern Region - Kelantan, Terengganu and Pahang (1.0000)

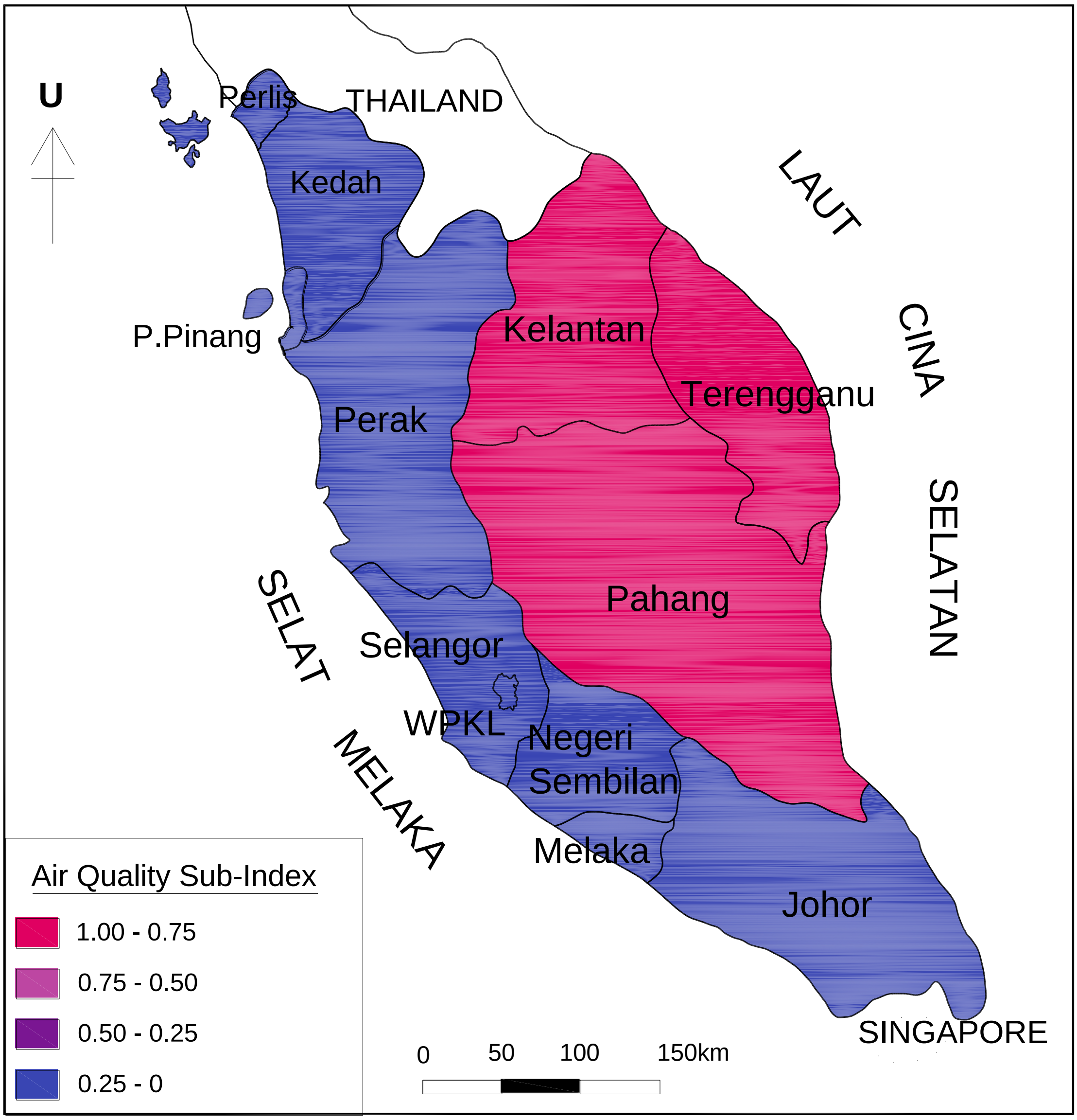


Figure 4.15: Air Quality Risk Map

4.3.7 Water Quality

According to AR4 and other studies, climate change may affect both the water quantity and quality of water resource (Hossain, 2001; IPCC, 2007; Salmivaara, 2009). The quantity of the water resources had been taken into consideration in the earlier section of climate change related natural hazards, namely flood and drought. In this section, water quality will be studied and compared against the amount of rainfall. The WQI for each state was obtained from the Department of Environment Malaysia from year 1984 to 2012. The states within Peninsular Malaysia have been categorized into 3 different regions, namely north-western, north-eastern and southern regions. North-western region comprises Perlis, Pulau Pinang, Kedah and Perlis, meanwhile north-eastern comprises Kelantan, Terengganu and Pahang. Selangor, WPKL, Negeri Sembilan, Melaka and Johor are the southern region. The annual water quality trend was generated for the three regions.

All the regions or states show a decrease in water quality trend from 1984 to 2012 as shown in Figure 4.16. All the states within Peninsular Malaysia are showing a steady decline of water quality index over the years. Water quality is closely interrelated with the immediate landuse that influence the discharge into the water bodies and the weather. The weather has major impact on water quality particularly Malaysia which receives approximately 2,400mm annually. As a result the decline in water quality might due to the increased of amount of rainfall expected and decreased of number of raindays (dry spells). The water pollutant is diluted with abundant of rainfall. Therefore, the water quality index is less significant to be included into the climate change vulnerability index.

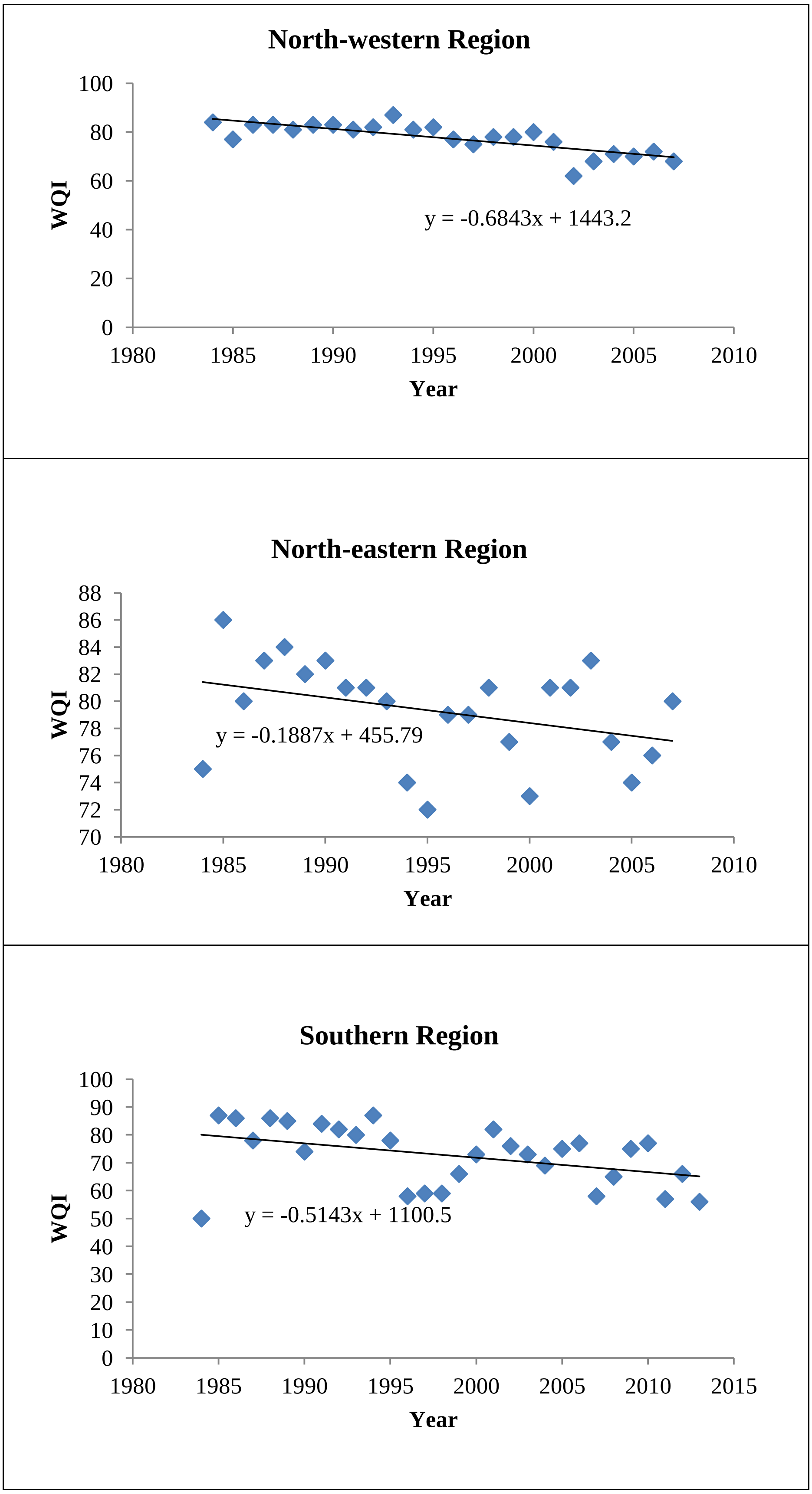


Figure 4.16: Trend for Water Quality Index

4.4 Coping Capacity

4.4.1 Geophysical Infrastructure

The geophysical infrastructures that were assessed in this study cover geographical elevation, road density, electricity coverage, potable water supply and communication network coverage. Table 4.16 shows the data for geophysical infrastructure obtained from relevant agencies and departments. First, the average elevation of each state above the mean sea-level was obtained from PRECIS. On average, Pahang state is located 453.5m above the mean sea-level. Titiwangsa Mountains (Banjaran Titiwangsa), also known as Main Range (Banjaran Besar) is the main mountain range which forms the backbone of Peninsular Malaysia. Most of this range is located in the State of Pahang. On the contrary, the Selangor is just located 42.1m above the mean sea-level and is the lowest among all the states.

Second is the road density factor with data on roads provided by the Public Works Department (PWD), Ministry of Works, Malaysia. The road density is defined as the length of road over the total area of a state. According to Table 4.16, WPKL had the densest road networks. WPKL, the capital of Malaysia which covers approximately 243km^2, had the most comprehensive road network that leads to the rest of Peninsular Malaysia. In addition, the total length of roads increased with the rapid development of highways and expressways. On the contrary, Pahang had the least dense road networks due to the mountainous terrain.

Third factor was the electricity coverage data provided by Tenaga Nasional Berhad. All the states had more than 97% coverage of electrical supply as shown in Table 4.16. The similar situation applies to the potable water supply except for the

Kelantan which recorded only 85.24% of population received potable water. The entire population that lives in WPKL (100%) receive potable water supply.

In terms of communication network coverage i.e. penetration rate for cellular telephone, WPKL recorded the highest number at 229.0 per 100 inhabitants in 2012. Pahang recorded the lowest number at 91.7 per 100 inhabitants as shown in Table 4.16.

The risk map for geographical elevation, road density, electricity coverage, potable water supply, and communication network coverage are shown in Figure 4.17, Figure 4.18, Figure 4.19, Figure 4.20 and Figure 4.21, respectively.

Table 4.16: Data of Coping Capacities from Various Sources

State	Geographical Elevation[1]	Road Density[2] (km/km^2)	Electricity Coverage[3] (%)	Potable water supply[4] (%)	Communication Network coverage[5]
Johor	63.0	0.71	98.88	99.21	126.5
Kedah	287.7	0.73	99.21	97.32	116.4
Kelantan	85.7	0.41	98.51	85.24	103.3
Melaka	382.2	1.28	99.59	99.79	182.3
Negeri Sembilan	81.5	1.22	99.11	99.45	158.4
Pahang	453.5	0.32	96.80	98.18	91.7
Perak	264.9	0.41	97.88	97.83	119.7
Perlis	348.8	1.31	99.40	98.72	124.5
Pulau Pinang	140.1	2.24	99.50	97.85	123.9
Selangor	42.1	1.79	98.66	99.72	145.4
Terengganu	227.3	0.52	98.95	99.28	125.3
WPKL	90.8	4.85	99.76	100.0	229.0

Source: [1] Providing Regional Climates for Impacts Studies (PRECIS)
[2] Public Works Department (PWD), Ministry of Works Malaysia
[3] Tenaga Nasional Berhad (TNB)
[4] National Water Services Commission (SPAN)
[5] Malaysian Communications and Multimedia Commission (MCMC)

Table 4.17: Elevation Sensitivity Sub-Index

Sub-Index	States
0 – 0.25	Pahang (0.0000), Melaka 90.1733)
0.2501 – 0.50	Perlis (0.2545), Kedah (0.4030), Perak (0.4584)
0.5001 – 0.75	Terengganu (0.5498)
0.7501 – 1.0	Pulau Pinang (0.7618), WPKL (0.8816), Kelantan (0.8940), Negeri Sembilan (0.9042), Johor (0.9492), Selangor (1.0000)

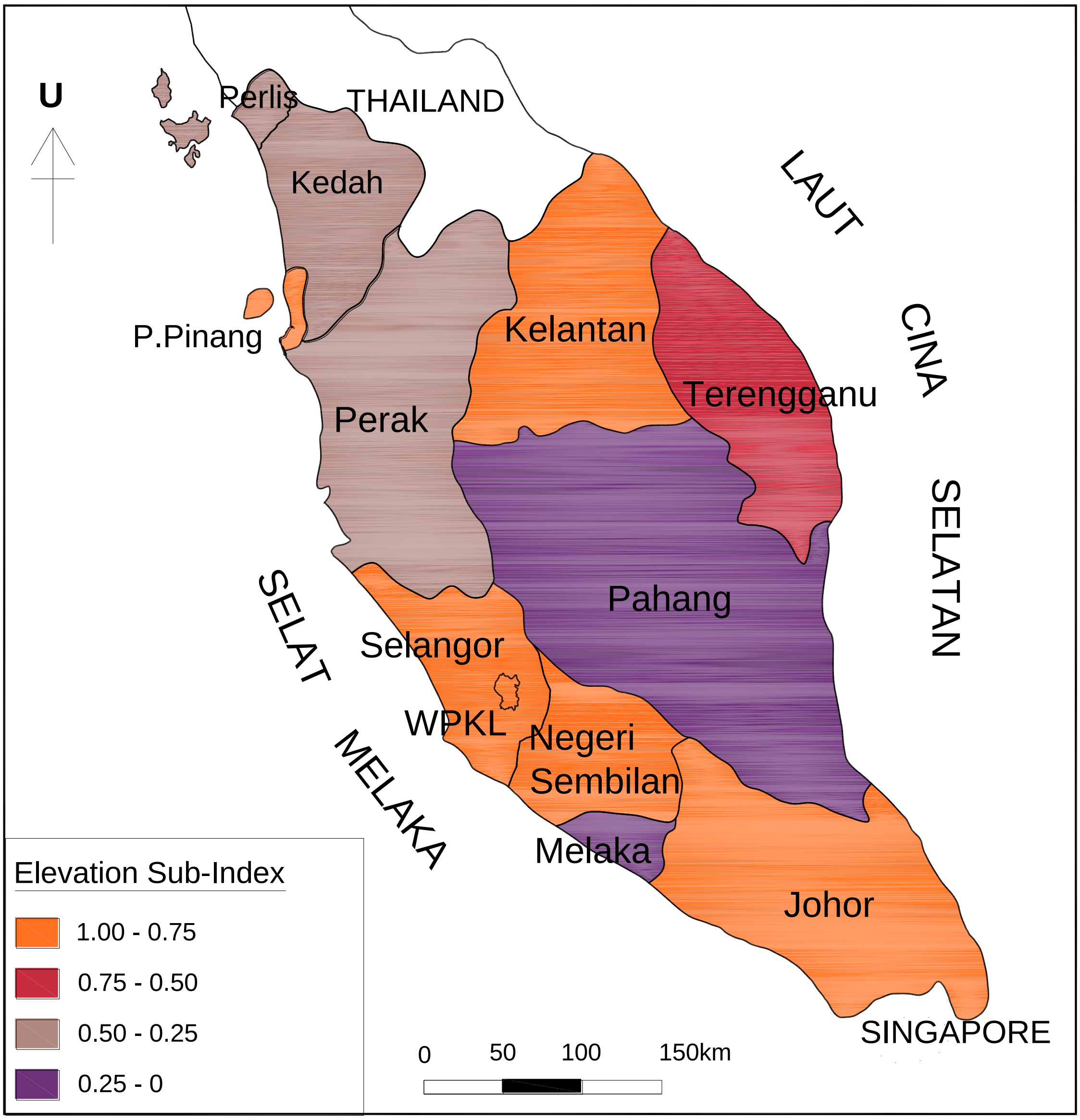


Figure 4.17: Elevation Sensitivity Map

Table 4.17 and Figure 4.17 concluded that geographical elevation poses the least risk to Pahang and Melaka while, Pulau Pinang, WPKL, Kelantan, Negeri

Sembilan, Johor and Selangor face the highest risk in terms of their geographical elevation.

Table 4.18: Road Density Sensitivity Sub-Index

Sub-Index	States
0 – 0.25	WPKL (0.0000)
0.2501 – 0.50	-
0.5001 – 0.75	Pulau Pinang (0.5762), Selangor (0.6755)
0.7501 – 1.0	Perlis (0.7815), Melaka (0.7881), Negeri Sembilan (0.8013), Kedah (0.9095), Johor (0.9139), Terengganu (0.9558), Kelantan (0.9801), Perak (0.9801), Pahang (1.0000)

As for the road infrastructure, WPKL as the capital of Malaysia has the densest road networks among all other states. This is followed by Pulau Pinang and Selangor. Finally, Perlis, Melaka, Negeri Sembilan, Kedah, Johor, Terengganu, Kelantan, Perak and Pahang were facing highest risk from climate change as illustrated in Figure 4.18 and tabulated in Table 4.18.

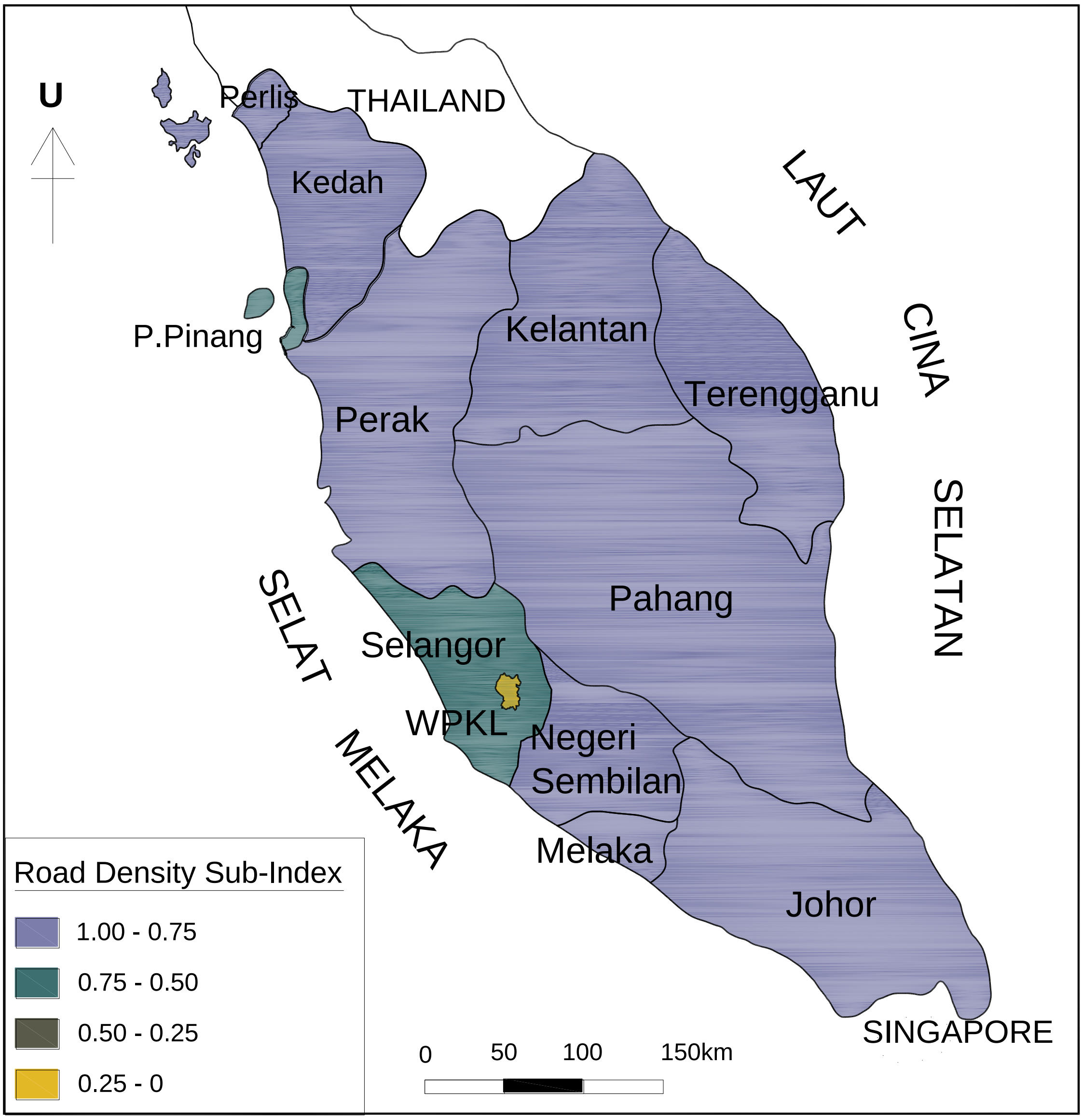


Figure 4.18: Road Density Sensitivity Map

Table 4.19 : Electricity Coverage Sensitivity Sub-Index

Sub-Index	**States**
0 – 0.25	WPKL (0.0000), Melaka (0.0574), Pulau Pinang (0.0878), Perlis (0.1216), Kedah (0.1858), Negeri Sembilan (0.2196)
0.2501 – 0.50	Terengganu (0.2736), Johor (0.2973), Selangor (0.3716), Kelantan (0.4223)
0.5001 – 0.75	Perak (0.6351)
0.7501 – 1.0	Pahang (1.0000)

Due to its mountainous terrain, Pahang has the lowest electricity coverage among all other states. Therefore, Pahang poses the highest risk in terms of the electricity coverage to overcome or absorb the climate change effects as shown in Table 4.19 and Figure 4.19. This is follow closely by Perak.

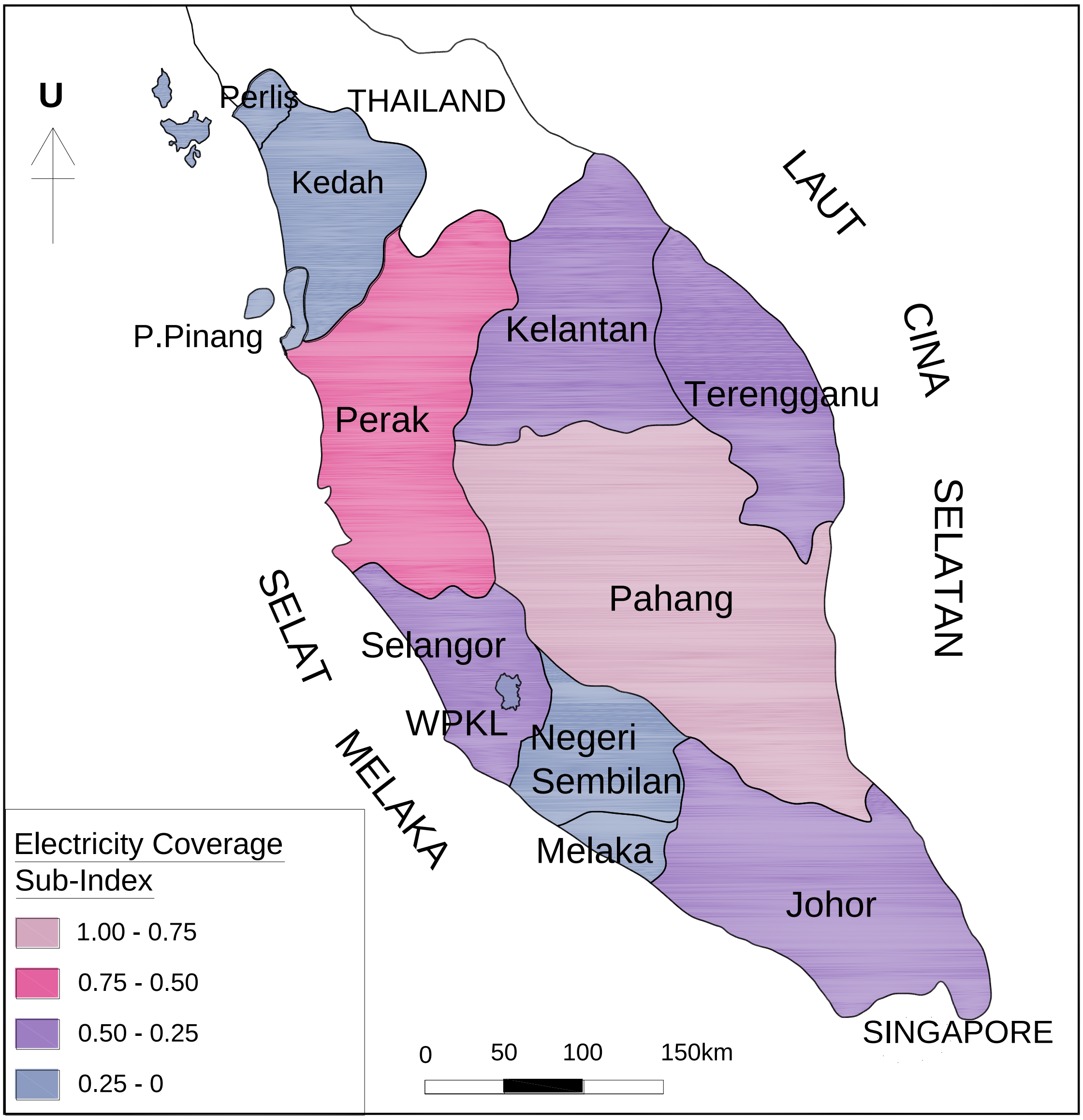


Figure 4.19: Electricity Coverage Sensitivity Map

Table 4.20: Potable Water Supply Sensitivity Sub-Index

Sub-Index	States
0 – 0.25	WPKL (0.0000), Melaka (0.0142), Selangor (0.0190), Negeri Sembilan (0.0373), Terengganu (0.0488), Johor (0.0535), Perlis (0.0867), Pahang (0.1233), Pulau Pinang (0.1457), Perak (0.1470), Kedah (0.1816)
0.2501 – 0.50	-
0.5001 – 0.75	-
0.7501 – 1.0	Kelantan (1.0000)

Kelantan is the only state that fell under the risky category of receiving potable water supply as shown in Table 4.20 and Figure 4.20. This means population in Kelantan is not well supplied with potable water compared with other states.

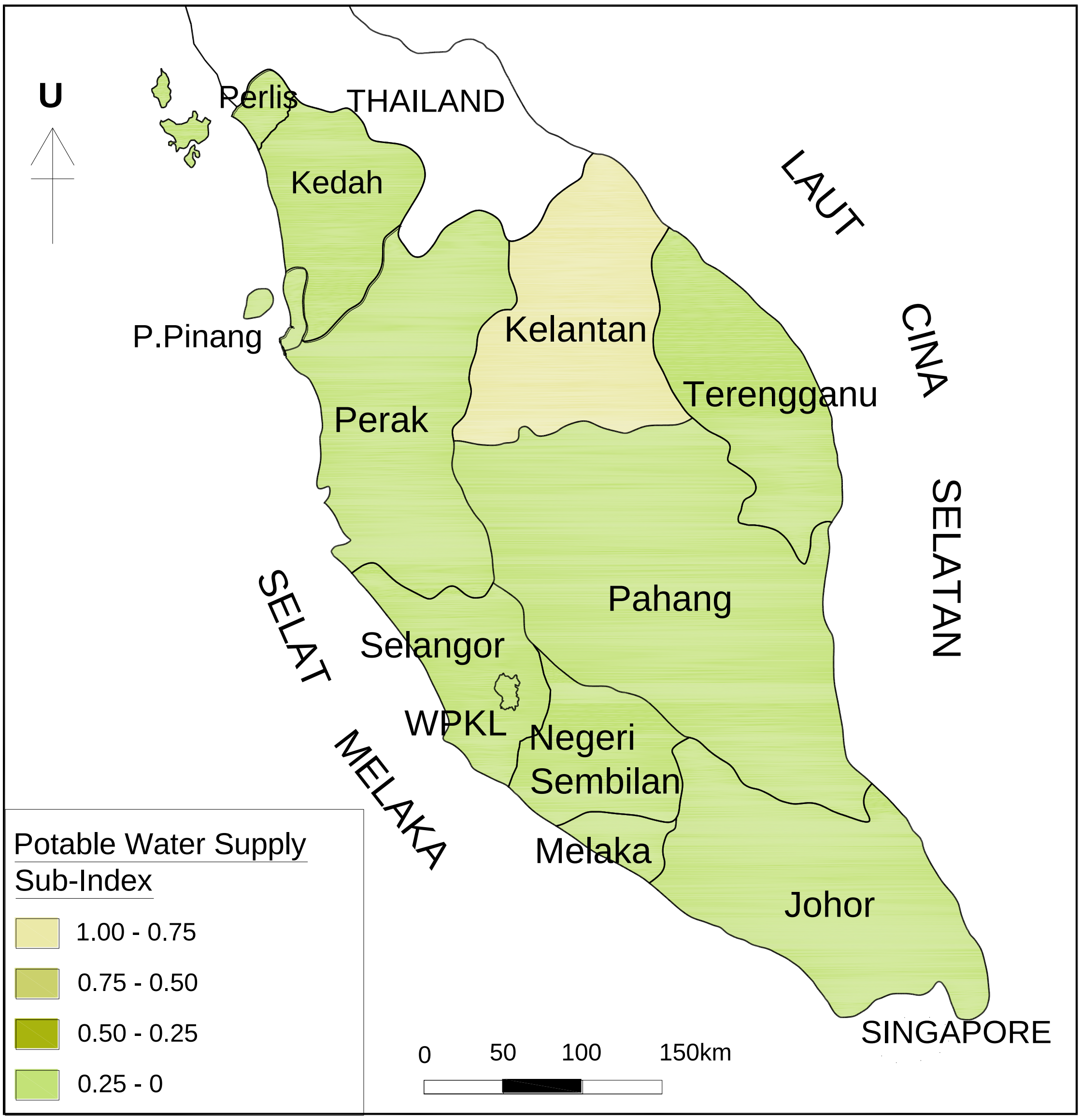


Figure 4.20: Potable Water Supply Sensitivity Map

Table 4.21: Communication Network Coverage Sensitivity Sub-Index

Sub-Index	States
0 – 0.25	WPKL (0.0000)
0.2501 – 0.50	Melaka (0.3401)
0.5001 – 0.75	Negeri Sembilan (0.5142), Selangor (0.6089), Johor (0.7465)
0.7501 – 1.0	Terengganu (0.7553), Perlis (0.7611), Pulau Pinang (0.7655), Perak (0.7961), Kedah (0.8201), Kelantan (0.9155), Pahang (0.1.0000)

From the communication coverage point of view, WPKL is the only state that recorded the lowest communication risk from Table 4.21 and Figure 4.21. Most of the population in WPKL has the access to good communication via mobile telephones.

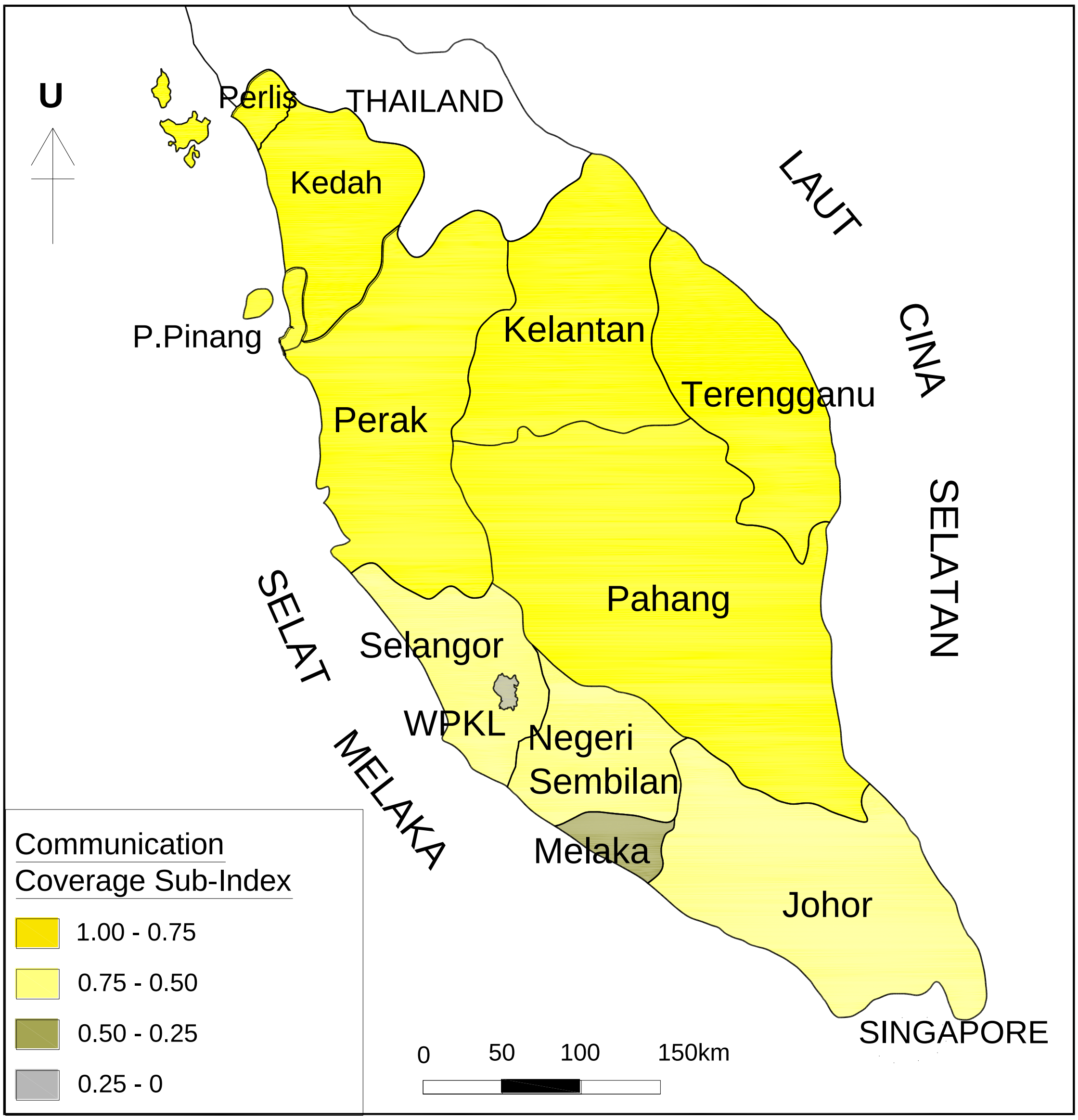


Figure 4.21: Communication Network Coverage Sensitivity Map

4.4.2 Gender Distribution

Table 4.22 shows the gender distribution recorded for all the states within the Peninsular Malaysia. From the table, Selangor had the highest number of males (2,579,194 people) and females (2,411,288 people) when compared with other states. The sex ratio is the ratio of males to females in a population. As tabulated in Table 4.22, men outnumbered women with the sex ratio in most of the states. For instance, the ratio of males to females was relatively high for Pahang (1.13), Johor (1.12), Negeri Sembilan (1.07) and Selangor (1.07). On the other hand, the Perlis was the only state where men were outnumbered by women (0.97).

Table 4.22: Gender Distribution by States in the Peninsular Malaysia

State	Male	Female	Sex Ratio
Johor	1,767,437	1,580,846	1.11
Kedah	985,398	962,253	1.02
Kelantan	773,698	765,903	1.01
Melaka	412,387	408,723	1.01
Negeri Sembilan	528,953	492,111	1.07
Pahang	796,367	704,450	1.13
Perak	1,187,073	1,165,670	1.02
Perlis	113,832	117,709	0.97
Pulau Pinang	782,061	779,322	1.01
Selangor	2,579,194	2,411,288	1.07
Terengganu	528,494	507,483	1.04
WPKL	852,130	822,491	1.04

Source : Department of Statistics Malaysia, 2012.

A t-distribution has been carried out to evaluate the difference between the actual and hypothetical mean or the true difference with a confidence interval of 90%. The t-distribution (or Student's t-distribution) was chosen when the sample size is mll (n<30) and/or when the population variance is unknown. Therefore, the test statistic is calculated using the sample standard deviation (s) formula when the population standard deviation (σ) is not known is : -

$$t = \frac{\chi - \mu}{s/\sqrt{n}}$$

Table 4.23: Significant Test for the Gender Distribution Parameter

State	Sex Ratio	Significant Test	Significant
Johor	1.11	1.75	X
Kedah	1.02	0.50	X
Kelantan	1.01	0.75	X
Melaka	1.01	0.75	X
Negeri Sembilan	1.07	0.75	X
Pahang	1.13	2.25	√
Perak	1.02	0.50	X
Perlis	0.97	1.75	X
Pulau Pinang	1.01	0.75	X
Selangor	1.07	0.75	X
Terengganu	1.04	0	X
WPKL	1.04	0	X
Mean (χ)	1.04	-	-
Standard Deviation (σ)	0.04	-	-

From the Table 4.23, there are 1 reading of the sample value fall has significant gender distribution, with 90% confidence interval. The only state has significant value of 2.25 ($\geqslant$1.796) is Pahang. Thus, the significant statistical evidence showing that the gender distribution will have severe negative impacts towards the vulnerability of human kinds in Peninsular Malaysia is rejected. Therefore, the gender distribution parameter is not included into the climate change vulnerability index.

4.4.3 Public Health

The public health parameter measures the incidence of a person's probability or risk of developing a disease within a specified period of time. The incidence rate shown in Table 4.24 is the number of new cases per 100,000 people in year 2012 for the dengue and the malaria. Selangor (263.85 per 100,000) and Pahang (13.06 per 100,000) recorded the highest incident rate for dengue and malaria, respectively. Most of the cases of dengue were recorded in the more developed states with a high population density. The states with high incidence rate per 100,000 for dengue were Selangor (263.85), WPKL (223) and Kelantan (214.28). Meanwhile Kedah, Perlis and Perak recorded lower than 100 cases per 100,000 people.

In other case, Pahang (13.06) and Kelantan (11.43) recorded high incidence rate per 100,000 people for malaria while Perlis had the lowest incidence rate of 0.43 for malaria.

Table 4.24: Incidence Rate (per 100,000 population) for Dengue and Malaria

State	Dengue	Malaria	Total
Johor	112.77	4.33	117.10
Kedah	40.00	6.26	46.26
Kelantan	214.28	11.43	225.71
Melaka	143.34	1.58	144.92
Negeri Sembilan	134.47	8.23	142.70
Pahang	104.74	13.06	117.80
Perak	95.89	3.44	99.33
Perlis	92.86	0.43	93.29
Pulau Pinang	116.12	7.11	123.23
Selangor	263.85	3.59	267.44
Terengganu	134.08	2.03	136.11
WPKL	223.00	3.32	227.01

Source : Ministry of Health, Malaysia, 2013.

Data from the Ministry of Health was collected and collated to produce the public health risk map as shown in Figure 4.22. The incidence rate for every 100,000 people was average with the total population for each state to get the overall public health risk. The map was produced with the data of incidence rate per total population for each of the state after normalization. Perlis was the high risk states that infected with dengue and malaria in year 2012. This means Perlis had highest incident rate of dengue and malaria per population through the year 2012.

Table 4.25: Public Health Risk Sub-Index

Public Health Risk Sub-Index	**States**
0 – 0.25	Kedah (0.0000), Johor (0.0324), Perak (0.0462), Selangor (0.0792), Pahang (0.1458), Pulau Pinang (0.1466)
0.2501 – 0.50	Terengganu (0.2910), WPKL (0.2961), Kelantan (0.3080), Negeri Sembilan (0.3215), Melaka (0.4502)
0.5001 – 0.75	-
0.7501 – 1.0	Perlis (1.0000)

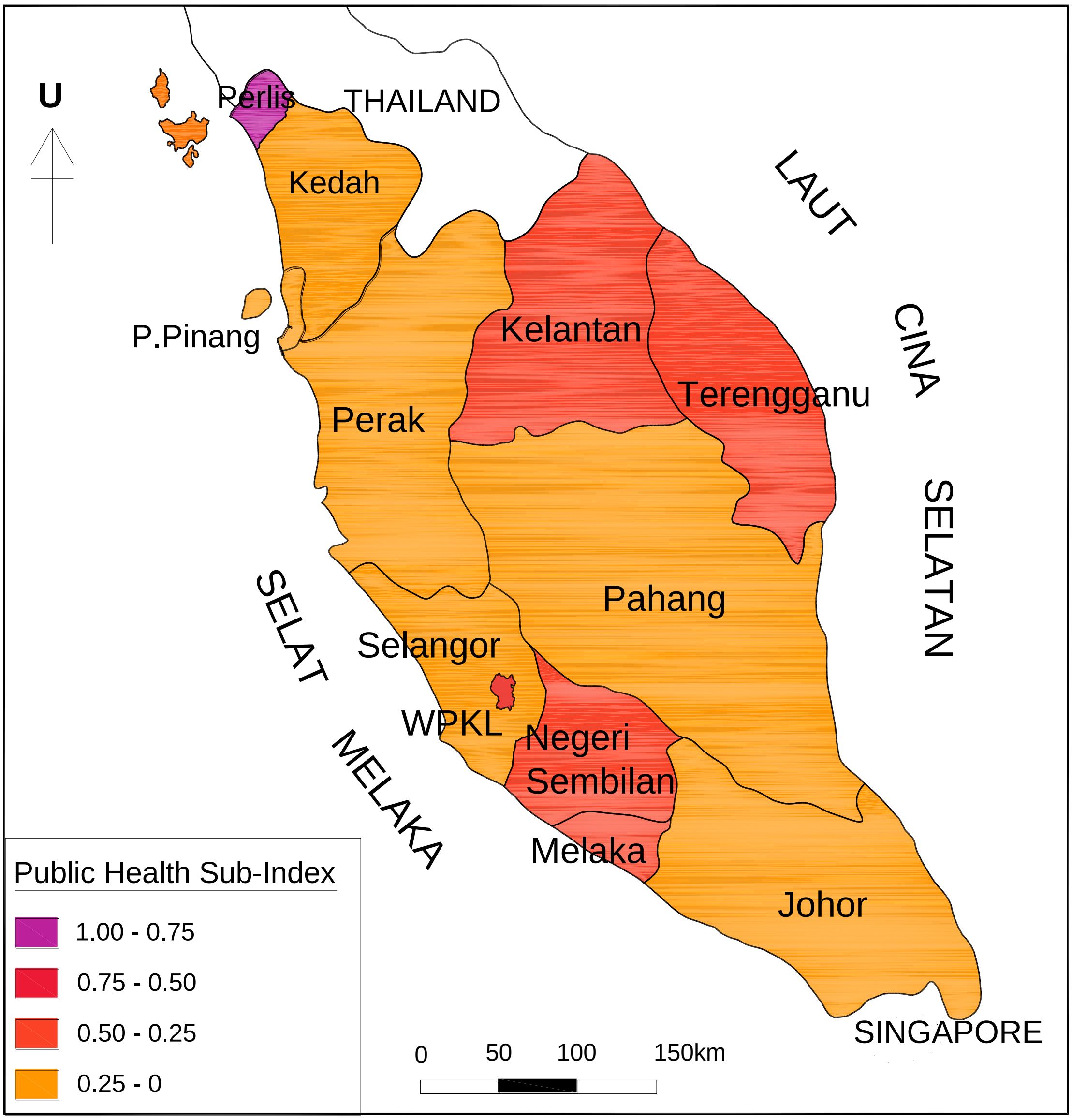


Figure 4.22: Public Health Risk Map

4.4.4 Literacy

The literacy rate is the percentage of the population aged 15 and above who can read and write a short, simple statement on their daily life. Generally, literacy also encompasses numeracy. From the result as shown in Table 4.26, WPKL recorded the highest literacy rate of 95.8%, followed by Selangor (95.1%) and Pulau Pinang (93.1%). Kelantan recorded the lowest literacy rate of 82.4% in year 2012.

Table 4.26 : Adult Literacy Rate

State	Adult literacy Rate (%)
Johor	92.3
Kedah	88.5
Kelantan	82.4
Melaka	91.3
N9	92.8
Pahang	91.0
Perak	89.7
Perlis	89.2
P.Pinang	93.1
Selangor	95.1
Tganu	87.2
WPKL	95.8

Source : Department of Statistics Malaysia, 2013.

A t-distribution has been carried out to evaluate the difference between the actual and hypothetical mean or the true difference of the incidence rate for every 100,000 people with a confidence interval of 90%. The test statistic is calculated using the sample standard deviation (s) formula when the population standard deviation (σ) is not known is : -

$$t = \frac{\chi - \mu}{s/\sqrt{n}}$$

Where χ is the sample mean value, μ is population mean value, s is sample standard error of the mean and n is sample size. From the t distribution table, $t_{0.05,\,11}$ =

1.796 at 90% confidence level with mean sample is 90.7 and standard deviation is 3.67 as shown in Table 4.27.

Table 4.27: Significant Test for the Literacy Parameter

State	Adult literacy Rate (%)	Significant Test	Significant
Johor	92.3	0.437	X
Kedah	88.5	0.600	X
Kelantan	82.4	2.264	√
Melaka	91.3	0.164	X
Negeri Sembilan	92.8	0.573	X
Pahang	91.0	0.082	X
Perak	89.7	0.273	X
Perlis	89.2	0.409	X
Pulau Pinang	93.1	0.655	X
Selangor	95.1	1.200	X
Terengganu	87.2	0.955	X
WPKL	95.8	1.391	X
Mean (χ)	90.7	-	-
Standard Deviation (σ)	3.67	-	-

The literacy rate was hypothesised to have a negative functional relationship in human vulnerability as well as the overall vulnerability to climate change as shown in Table 3.5. As presented in the Table 4.27, there is only one state, Kelantan, with 90% confidence interval showing significant statistical evidence the adult literacy will have severe negative impacts towards the vulnerability of human kinds in Peninsular Malaysia. Therefore, the adult literacy parameter is not included into the climate change vulnerability index.

4.5 Vulnerability Assessment

Iyengar and Sudarshan (1982) established a method to develop a composite index from multivariate data and it was used to rank the districts according to their economic performance. Yet, this methodology is statistically and well suited with the development of composite index of vulnerability to climate change (Hiremath &

Shiyani, 2013). This method has been adopted by a few recent research papers (Chakrabarty, 2012; Hiremath & Shiyani, 2013). The choice of the weights in this manner would ensure that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter regional comparisons. The vulnerability index so computed lies between 0 and 1, with 1 indicating maximum vulnerability and 0 indicating no vulnerability at all.

The weightage for each of the sub-indexes i.e. climate, natural hazards, infrastructure, human vulnerability, social vulnerability, economic vulnerability and environmental vulnerability after normalization is shown in Figure 4.23. The sum of the weightage of fifteen (15) sub-indexes from climate change trends, climate-related natural hazards, physical vulnerability, social vulnerability, economic vulnerability and environmental vulnerability categories is equal to 1.0. The weight of 14.64% was assigned to temperature and rainfall under the climate change trends. Another 6.67% was allocated to flood risk which fell under climate-related natural hazards. The major portion, 33.93%, consists of the coping ability or infrastructure namely geographical elevation, road density, electricity coverage, potable water supply, and communication networks coverage. The human factor consists of public health contributes 7.16%. Another 20.52% covers by the social vulnerability from the construction of population density, dependency ratio and health facilities. Then, the economic vulnerability (12.73%) was made up from poverty and gross domestic product. The final percentage was for the environmental vulnerability (4.37%). Air pollution fell under the environmental vulnerability category.

The ranking and state according to climate change vulnerability index is presented in Table 4.29 and Figure 4.24. Kelantan is the most vulnerable state in

Peninsular Malaysia with the climate change vulnerability index score 0.7061 out of 1.0. This was followed by Perlis (0.6177), Terengganu (0.5383), Johor (0.5324), Kedah (0.5285), Pahang (0.4817), Perak (0.4690), Negeri Sembilan (0.4606), Melaka (0.4231), Pulau Pinang (0.3913), Selangor (0.3694), and finally WPKL (0.2582).

An important goal of such vulnerability assessment is to create an index of overall vulnerability from a composite index. These could be related to natural hazards, infrastructure, human, social, economic and environmental factors that act simultaneously together with climate change. Hence, it can be well represented by a set of composite indexes. Composite indexes are used to gauge the vulnerability of each state to climate change. With the newly developed index, each state is classified based on a set of large multivariate data. Vulnerability due to climate change can be very subjective. The selected components chosen in this study are climate, natural hazards, infrastructure, human, social, economic and environmental vulnerability. Each of the components is consists of several sub-indicators. The method proposed by Iyengar and Sudarshan (1982) are used for this study. This method alters the indicator variable which lies between 0 and 1. In addition, it does not have the restrictive assumption of linearity in relation to indicators, where the weights are inversely proportional to standard deviations.

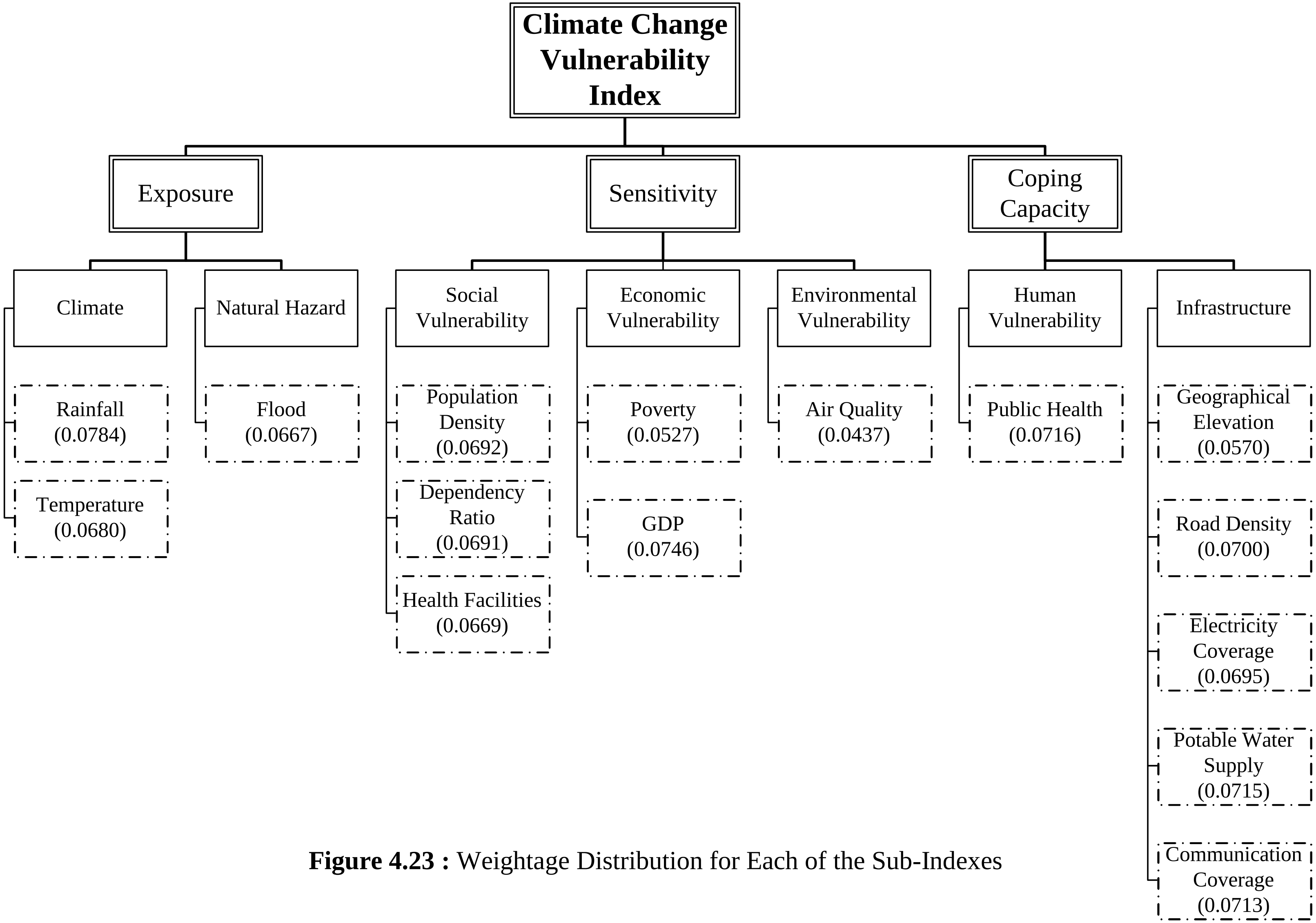


Figure 4.23 : Weightage Distribution for Each of the Sub-Indexes

Table 4.28: Component-wise and overall vulnerability indices for Peninsular Malaysia

State	Exposure				Sensitivity						Coping Capacity			
	Climate Change		Natural Hazard		Social Vulnerability		Economic Vulnerability		Environmental Vulnerability		Infrastructure		Human Vulnerability	
Johor	0.1341	(1)	0.0417	(4)	0.0961	(5)	0.0625	(7)	0.0000	(8)	0.1957	(4)	0.0023	(11)
Kedah	0.0891	(7)	0.0355	(5)	0.1189	(2)	0.1127	(3)	0.0013	(4)	0.1710	(7)	0.0000	(12)
Kelantan	0.0902	(6)	0.0120	(11)	0.1366	(1)	0.1158	(2)	0.0437	(1)	0.2856	(1)	0.0221	(4)
Melaka	0.1142	(4)	0.0512	(3)	0.0823	(9)	0.0489	(8)	0.0000	(8)	0.0943	(11)	0.0323	(2)
Negeri Sembilan	0.1143	(3)	0.0186	(8)	0.0961	(5)	0.0464	(9)	0.0000	(8)	0.1622	(8)	0.0230	(3)
Pahang	0.0204	(12)	0.0193	(7)	0.1010	(3)	0.0673	(6)	0.0437	(1)	0.2195	(2)	0.0104	(8)
Perak	0.0664	(10)	0.0184	(9)	0.0824	(8)	0.0911	(4)	0.0013	(4)	0.2061	(3)	0.0033	(10)
Perlis	0.1233	(2)	0.0667	(1)	0.1004	(4)	0.1163	(1)	0.0013	(4)	0.1381	(10)	0.0716	(1)
Pulau Pinang	0.0591	(11)	0.0519	(2)	0.0718	(10)	0.0419	(10)	0.0013	(4)	0.1548	(9)	0.0105	(7)
Selangor	0.0835	(9)	0.0000	(12)	0.0651	(12)	0.0404	(11)	0.0000	(8)	0.1748	(5)	0.0057	(9)
Terengganu	0.0886	(8)	0.0275	(6)	0.0921	(7)	0.0910	(5)	0.0437	(1)	0.1745	(6)	0.0208	(6)
WPKL	0.0974	(5)	0.0183	(10)	0.0692	(11)	0.0019	(12)	0.0000	(8)	0.0502	(12)	0.0212	(5)

Note: Number in bracket () denotes the ranking of the state.

Table 4.29: Climate Change Vulnerability Index

Rank	State	Climate Change Vulnerability Index
1	Kelantan	0.7061
2	Perlis	0.6177
3	Terengganu	0.5383
4	Johor	0.5324
5	Kedah	0.5285
6	Pahang	0.4817
7	Perak	0.4690
8	Negeri Sembilan	0.4606
9	Melaka	0.4231
10	Pulau Pinang	0.3913
11	Selangor	0.3694
12	WPKL	0.2582

Table 4.30: State Ranks - Climate Change Vulnerability Index

Climate Change Vulnerability Index	States
0.8001 – 1.0 (Very high)	-
0.6001 – 0.7999 (Moderately High)	Kelantan, Perlis
0.4000 – 0.5999 (Moderate)	Terengganu, Johor, Kedah, Pahang, Perak, Negeri Sembilan, Melaka
0.2001 – 0.3999 (Moderately Low)	Pulau Pinang, Selangor, WPKL
0 – 0.2000 (Low)	-

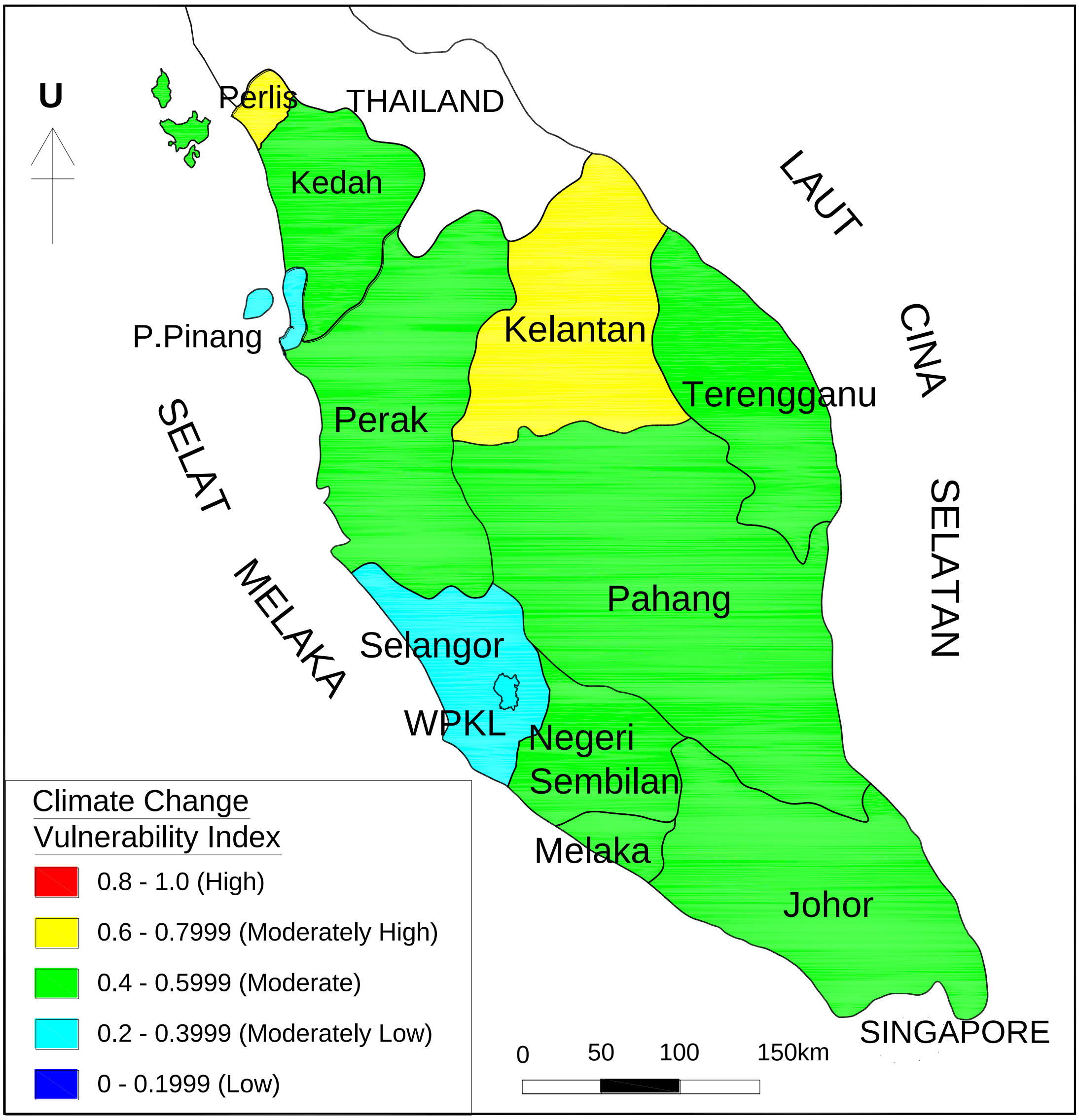


Figure 4.24: Climate Change Vulnerability Map

4.6 Statistical Test of the Developed Index

The statistical test of the components of climate change vulnerability index is by analyzing the rank of each state using Friedman test and Kendall's Coefficient of Concordance (Kendall's W) and the results of the analysis are shown in Table 4.31. Both Friedman test and Kendall's are a non-parametric statistic. Both the statistic test are related, but Kendall's W is more naturally and easily interpreted. It measures the extent to which the components are in agreement with the climate change. Kendall's W is a normalization of the Friedman test statistics and been used to assess the agreement among the ranks. Kendall's W ranges from 0 (no agreement) to 1 (complete agreement). The confidence in the degree of agreement, Kendall's W provides a measure to assess the degree of consensus achieved and level of confidence in mean ordinal ranks and statistically significant.

As shown in the table, the Kendall's W value was computed as 0.4476. This indicates that the components are fairly agreed in their rankings of climate change. This is considerably lower than 50% of the significance. However, it is well away from complete lack of concordance (W = 0). In fact, other factors such as the limitations of the model and data scarcity contribute to the divergence of the Kendall's W from the complete agreement. In the overall, limitation and uncertainties of the data derived from climate modeling system, PRECIS such as temperature and rainfall is one of the divergence contributions. In addition, the chosen components and sub- indicators, arrangement, weightage and distribution of the selected parameters may also lead to deviation of the Kendall's W from total agreement (W = 1).

Table 4.31: Reliability Statistic for the Climate Change Vulnerability Index

Measure	Value
Sum of squared deviation, *S*	2,304
Kendall’s *W*	0.4476
Friedman’s chi-square, X^2	29.5385
Chi-square distribution P-value	0.001872 (p<0.005)

As shown in the Table 4.31, the Kendall’s W, a statistical value obtained from analyzing ranking of six identified climate change components, 0.4476 is significant at 0.1% (Friedman’s chi-square = 29.5385, $p < 0.005$).

The Friedman test shows that there is a statistically significant finding. The chi-square probability value, p = 0.001872, which a p-value less than 0.05 is said to be statistically significant. From Table 4.31, the significance of Kendall’s W and Friedman test are clearly shows that the newly developed index has significance concordance, and all indicators contribute to the overall concordance of this index.

CHAPTER 5

DISCUSSION

As discussed in the earlier chapter, assessment of vulnerability to climate change is discussed in the context of *exposure*, *sensitivity* and *coping capacity* of the society. Under the exposure component, climate variability and climate related natural hazard recorded for the trends of a period of 61 years from 1960 to 2020. Assessment of sensitivity or the degree to which the population is affected by exposure is described in terms population density, gender distribution, public health status, poverty, gross domestic product, and air quality. These were considered for the discussion of sensitivity since these are basic requirements for human survival. Given the analysis of *exposure* and *sensitivity*, the *coping capacity* of the population to withstand or recover from the exposure has been discussed in terms of the geographical elevation, road density, electricity coverage, potable water supply, communication network coverage, literacy and health facilities.

The analysis and assessment of the climate variability (temperature and rainfall) and climate related natural hazard (flood) components identified in contributing to climate change vulnerability has been carried out in a period of 61 years from 1960 encroaching to 2020. The trends from the past, present and future has been captured in a linear regression. Beside the climate variability (temperature and rainfall) and climate related natural hazard (flood) components, other components fall under sensitivity and adaptive capacity are assessed in current year (2012). Therefore, the developed climate changes vulnerability index is applicable with an assumption that the components in sensitivity and adaptive capacity remain unchanged or status quo. The prediction and changes of future climate and climate related hazard with the current infrastructure, human, social economic and environmental conditions has been reflected and taking account into the analysis.

The analysis and assessment show that climate has and will severely impact the country. The country's livelihood systems are highly dependent on natural resources, which are very sensitive to any slight changes in climatic conditions. This makes the country very vulnerable to climate change.

Although actual scores are presented it is worth reinforcing that these have been created by standardising indicators across the range of data for Peninsular Malaysia, not across a normative range with theoretical high and low values. Therefore those states at the top end of the range with "high" scores nearing one have the highest relative vulnerability. The states at the bottom of the range with "low" scores nearer to zero do not necessarily have low absolute human vulnerabilities; rather they are slightly better off compared to other states in Peninsular Malaysia.

Kelantan is the most vulnerable state in Peninsular Malaysia as shown in the results from the evaluation and assessment of the previous chapter. Kelantan has the highest score of 0.7061 for the overall climate change vulnerability index. The index has taken account of climate change parameters, climate related natural hazards, infrastructure, human vulnerability, social vulnerability, economic vulnerability, and environmental vulnerability.

The end result was found to be in line with the study carried by the Economy and Environment Program for Southeast Asia. The developed climate change vulnerability index consisted of multiple hazard index, sensitivity index, index of inverse adaptive capacity, population density, protected area, total population, income per capita, poverty incidence and human development index. According to the Climate Change Vulnerability Mapping for Southeast Asia by Yusuf and Francisco (2009), Sabah had the highest ranking with a score of 0.23 in the climate change vulnerability index. However, East Malaysia namely, Sabah and Sarawak, were not included and assessed in this study. Therefore, the second highest ranking is followed by Kelantan with a score of 0.20.

In addition, Pulau Pinang was listed as the third most vulnerable state by Yusuf and Francisco (2009) after Kelantan. In contrast, Perlis was the second most vulnerable state in this study with a climate change vulnerability index score of 0.6177 whilst Pulau Pinang was ranked as the tenth most vulnerable state. The climate change vulnerability index for Pulau Pinang was 0.3913.

The different and dissimilarity between the results from this study and Climate Change Vulnerability Mapping for Southeast Asia by Yusuf and Francisco (2009) attributable to a few different opinions and point of views in the analysis and assessment. For instance, there are a few arguments from the Climate Change Vulnerability Mapping for Southeast Asia by Yusuf and Francisco (2009). Firstly, the climate hazard maps was a superimposed of five climate-related risks, namely tropical cyclones, floods, landslides, droughts and sea-level rise. However, most of the risks except for sea-level rise used historic data of occurrence. The only parameter that considered the climate change impacts was the sea-level inundation. Yet, a simplistic model of inundated zone map of a five-meter sea-level rise was used. Secondly, all the five hazards were weight equally. Finally, the equal weightage was given to the other climate change vulnerability parameter such as population, biodiversity and adaptive capacity.

As referred to the argument from Climate Change Vulnerability Mapping for Southeast Asia, some fine-tuning analysis with new data and using statistical approaches has been carried out in this study. A historical and near-future trend from 1960 to 2020 was used to analyse and project the climate related natural hazards namely, flood and drought. In addition, a multivariate index was used to compute into a single comparable vulnerability index. A huge amount of diverse selected parameters was selected based on previous research from various literatures. The multivariate indicators were normalized and different and unequal weightage was given accordingly. Statistical test and analysis were performed within and between the components of parameters.

Although every attempt was made to eliminate possible shortcomings, this study does have several limitations. One of the primary limitations was using user-defined selected indicators, which were used to explore the implications of climate change vulnerability map. The selection of indicators is very much based on personal decisions and historical research. Another limitation for this study was the lack of specific quantitative data or information (IPCC, 2012). Accessibility and consistency of data and information between various government agencies are almost impossible. As a result, selection of indicators has been restricted indirectly. The third and final limitation was the indicators are very much influenced by the scaling and weighting. The final vulnerability index score is a composite of multi-dimensional indicators. The selected indicator are weighted and scaled with the Kendall’s coefficient of condordance or Kendall’s W.

CHAPTER 6

CONCLUSION, LIMITATIONS AND RECOMMENDATION FOR FUTURE RESEARCH

6.1 Summary and Conclusion

This study has derived a theory-driven aggregate index of climate change trends, climate related natural hazards components, physical components, social components, economic components, and environmental components. Different weightages have been giving to different indicators to avoid any one indicator dominating and distorting the inter-state comparisons. The proposed indicator system provides an efficient method and tool to methodology on a local level. It helps to generate information, which is then applied by decision-makers to better manage likely impacts of natural hazards.

The outcome, which shows current vulnerability to climate change, puts Kelantan as the most vulnerable state in Peninsular Malaysia, whilst WPKL is the least vulnerable, although it is important to remember that this is a relative scale and should not imply that the latter states are entirely resilient.

For Peninsular Malaysia, the adaptation policy formulation and planning should be based on the risk specific exposure issues related to climate change. Such a strategy is envisaged to strengthen the selected community capacities for adaptation to recurring risks. In this study, prioritizing the adaptation formulation and planning according to specific climate change vulnerability are shown in Table 6.1.

Table 6.1: Prioritized Districts for Adaptation Formulation and Planning

Rank	State	Risk/Exposure														
		Temperature	Rainfall	Flood	Geographical Elevation	Road Density	Electricity Coverage	Potable Water Supply	Communication Network Coverage	Public Health	Population Density	Dependency Ratio	Health Facilities	Poverty	Gross Domestic Product	Air Quality
1	Kelantan				√	√		√	√			√	√	√	√	√
2	Perlis	√	√	√		√			√	√			√	√	√	
3	Terengganu					√			√				√		√	√
4	Johor	√	√		√	√										
5	Kedah					√			√			√	√	√	√	
6	Pahang					√	√		√				√			√
7	Perak					√			√			√			√	
8	Negeri Sembilan	√			√	√										
9	Melaka	√	√	√		√										
10	Pulau Pinang		√	√	√				√							
11	Selangor				√								√			
12	WPKL	√			√						√					

6.2 Limitations

There are three limitations in this study. Firstly, selection of the indicators is based the availability of data, personal decision or historical research. The science of climate change is inherently uncertain due to the large gaps in knowledge for the newly developing scientific research of climate change in Malaysia.

Second is an interpretation of the vulnerability index. Developments of the vulnerability index are sometimes inappropriate and inconsistent due to the quality of data. There are some inherent problems in constructing such a composite index as the quality and comparability of statistics varies from state to state and data provided by relevant government agencies.

Finally, the results are also influenced by the scaling and weighting of the indicators. Vulnerability index is a composite of multidimensional indicators to produce a single number to ease the comparison with different states. Therefore, the index construction specifies should have a robust internal correlation between the variety indicators. The selected indicators should then be weighted and scaled appropriately, according to the vast different impact of the hazards.

Due to the data limitation and personal judgement in the indicator selection, there is always room for improvement of the sensitivity, risk/exposure and coping abilities of the indexes.

6.3 Recommendation for Future Research

Once the vulnerable state has been identified, for example Kelantan and Perlis, adaptation policy formulation and planning could be implemented to respond to the impacts of climate change on a priority basis. This study is an endeavour to identify the most vulnerable state in Peninsular Malaysia. Hence, the adaptation planning and implementation is able to focus on the communities exposed to the specific risks. Since each communities have different extent and tolerance to the exposed risks, a further analysis and assessment should be carried out for targeting the vulnerable communities. A series of customized and specific adaptation measures could only be developed with the understanding of the characteristics and features of each community.

In conclusion, there is no single adaptation measure which could be employed throughout the entire Peninsular Malaysia even though the states are exposed to the same set of risks. It is mainly dependent upon the extent of the exposure, sensitivity to its impacts and the capabilities of the communities towards the risks.

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Appendix 1 : Parameter for Vulnerability Indicator Increase with Increase in the Value of Indicator

States	Temp.	Normalised Score	Rainfall	Normalised Score	Flood	Normalised Score	Population	Normalised Score	Public Health	Normalised Score	Poverty	Normalised Score
Johor	0.0221	0.8200	2.0880	1.0000	1.2200	0.6250	180	0.0195	0.0358	0.0324	1.3	0.1455
Kedah	0.0204	0.4800	0.2506	0.7205	0.8000	0.5329	211	0.0240	0.0238	0.0000	5.3	0.8727
Kelantan	0.0215	0.7000	-0.9080	0.5443	-0.8100	0.1798	109	0.0094	0.1377	0.3080	4.8	0.7818
Melaka	0.0218	0.7600	0.7597	0.7980	1.8700	0.7675	507	0.0662	0.1903	0.4502	0.5	0.0000
N. Sembilan	0.0230	1.0000	-0.5977	0.5915	-0.3600	0.2785	158	0.0164	0.1427	0.3215	0.7	0.0364
Pahang	0.0195	0.3000	-4.4870	0.0000	-0.3100	0.2895	43	0.0000	0.0777	0.1458	2.1	0.2909
Perak	0.0198	0.3600	-0.9704	0.5348	-0.3700	0.2763	115	0.0103	0.0409	0.0462	3.5	0.5455
Perlis	0.0222	0.8400	1.0698	0.8451	2.9300	1.0000	292	0.0355	0.3936	1.0000	6.0	1.0000
P.Pinang	0.0180	0.0000	0.4734	0.7544	1.9200	0.7785	1538	0.2133	0.0780	0.1466	1.2	0.1273
Selangor	0.0209	0.5800	-0.7920	0.5620	-1.6300	0.0000	694	0.0929	0.0531	0.0792	0.7	0.0364
Terengganu	0.0202	0.4400	0.4386	0.7491	0.2500	0.4123	84	0.0058	0.1314	0.2910	4.0	0.6364
WPKL	0.0222	0.8400	-1.1019	0.5148	-0.3800	0.2741	7052	1.0000	0.1333	0.2961	0.7	0.0364

Appendix 2 : Parameter for Vulnerability Indicator Decrease with Increase in the Value of Indicator

States	Elevation	Normalised Score	Road	Normalised Score	Electricity	Normalised Score	Water	Normalised Score
Johor	63.0	0.9492	0.71	0.9139	98.88	0.2973	99.21	0.0535
Kedah	287.7	0.4030	0.73	0.9095	99.21	0.1858	97.32	0.1816
Kelantan	85.7	0.8940	0.41	0.9801	98.51	0.4223	85.24	1.0000
Melaka	382.2	0.1733	1.28	0.7881	99.59	0.0574	99.79	0.0142
N. Sembilan	81.5	0.9042	1.22	0.8013	99.11	0.2196	99.45	0.0373
Pahang	453.5	0.0000	0.32	1.0000	96.80	1.0000	98.18	0.1233
Perak	264.9	0.4584	0.41	0.9801	97.88	0.6351	97.83	0.1470
Perlis	348.8	0.2545	1.31	0.7815	99.40	0.1216	98.72	0.0867
P.Pinang	140.1	0.7618	2.24	0.5762	99.50	0.0878	97.85	0.1457
Selangor	42.1	1.0000	1.79	0.6755	98.66	0.3716	99.72	0.0190
Terengganu	227.3	0.5498	0.52	0.9558	98.95	0.2736	99.28	0.0488
WPKL	90.8	0.8816	4.85	0.0000	99.76	0.0000	100	0.0000

States	Health Facilities	Normalised Score	GDP	Normalised Score	Air Quality	Normalised Score
Johor	1.8510	0.7478	20911	0.7349	2.7906	0.0000
Kedah	1.4347	0.8901	13294	0.8947	2.5865	0.0300
Kelantan	1.1135	1.0000	8273	1.0000	-4.0058	1.0000
Melaka	2.5853	0.4966	24697	0.6555	2.7906	0.0000
N. Sembilan	1.9654	0.7086	27485	0.5970	2.7906	0.0000
Pahang	1.3978	0.9028	22743	0.6965	-4.0058	1.0000
Perak	2.7694	0.4336	16088	0.8361	2.5865	0.0300
Perlis	1.7131	0.7949	15296	0.8527	2.5865	0.0300
P.Pinang	2.9937	0.3569	33456	0.4718	2.5865	0.0300
Selangor	1.8335	0.7537	31363	0.5157	2.7906	0.0000
Terengganu	1.3545	0.9176	19225	0.7703	-4.0058	1.0000
WPKL	4.0373	0.0000	55951	0.0000	2.7906	0.0000

Appendix 3: Unequal Weightage Distribution

States	Temperature	Rainfall	Flood	Elevation	Road	Electricity	Water	Communication
Johor	0.8200	1.0000	0.6250	0.9492	0.9139	0.2973	0.0535	0.7465
Kedah	0.4800	0.7205	0.5329	0.4030	0.9095	0.1858	0.1816	0.8201
Kelantan	0.7000	0.5443	0.1798	0.8940	0.9801	0.4223	1.0000	0.9155
Melaka	0.7600	0.7980	0.7675	0.1733	0.7881	0.0574	0.0142	0.3401
N. Sembilan	1.0000	0.5915	0.2785	0.9042	0.8013	0.2196	0.0373	0.5142
Pahang	0.3000	0.0000	0.2895	0.0000	1.0000	1.0000	0.1233	1.0000
Perak	0.3600	0.5348	0.2763	0.4584	0.9801	0.6351	0.1470	0.7961
Perlis	0.8400	0.8451	1.0000	0.2545	0.7815	0.1216	0.0867	0.7611
P.Pinang	0.0000	0.7544	0.7785	0.7618	0.5762	0.0878	0.1457	0.7655
Selangor	0.5800	0.5620	0.0000	1.0000	0.6755	0.3716	0.0190	0.6089
Terengganu	0.4400	0.7491	0.4123	0.5498	0.9558	0.2736	0.0488	0.7553
WPKL	0.8400	0.5148	0.2741	0.8816	0.0000	0.0000	0.0000	0.0000
Standard Deviation	0.2871	0.2489	0.2926	0.3423	0.2789	0.2809	0.2728	0.2737
Variance	0.0824	0.0620	0.0856	0.1172	0.0778	0.0789	0.0744	0.0749
Constant	0.0195							
Weightage	0.0680	0.0784	0.0667	0.0570	0.0700	0.0695	0.0715	0.0713

Appendix 3 :Unequal Weightage Distribution (Cont')

States	Health Facilities	Poverty	GDP	Air Pollution
Johor	0.7478	0.1455	0.7349	0.0000
Kedah	0.8901	0.8727	0.8947	0.0300
Kelantan	1.0000	0.7818	1.0000	1.0000
Melaka	0.4966	0.0000	0.6555	0.0000
N. Sembilan	0.7086	0.0364	0.5970	0.0000
Pahang	0.9028	0.2909	0.6965	1.0000
Perak	0.4336	0.5455	0.8361	0.0300
Perlis	0.7949	1.0000	0.8527	0.0300
P.Pinang	0.3569	0.1273	0.4718	0.0300
Selangor	0.7537	0.0364	0.5157	0.0000
Terengganu	0.9176	0.6364	0.7703	1.0000
WPKL	0.0000	0.0364	0.0000	0.0000
Standard Deviation	0.2917	0.3701	0.2616	0.4464
Variance	0.0851	0.1370	0.0684	0.1993
Constant	0.0195			
Weightage	0.0669	0.0527	0.0746	0.0437

Appendix 4: Climate Change Vulnerability Index

Component	Climate Change		Natural Hazard	Infrastructure					Human Vulnerability
States	**Temp**	**Rainfall**	**Flood**	**Geographical Elevation**	**Road Density**	**Electricity Coverage**	**Potable Water Supply**	**Communication Network Coverage**	**Public Health**
Johor	0.0557	0.0784	0.0417	0.0541	0.0639	0.0207	0.0038	0.0532	0.0023
Kedah	0.0326	0.0565	0.0355	0.0230	0.0636	0.0129	0.0130	0.0585	0.0000
Kelantan	0.0476	0.0427	0.0120	0.0510	0.0686	0.0293	0.0715	0.0653	0.0221
Melaka	0.0516	0.0625	0.0512	0.0099	0.0551	0.0040	0.0010	0.0242	0.0323
N. Sembilan	0.0680	0.0464	0.0186	0.0515	0.0561	0.0153	0.0027	0.0367	0.0230
Pahang	0.0204	0.0000	0.0193	0.0000	0.0700	0.0695	0.0088	0.0713	0.0104
Perak	0.0245	0.0419	0.0184	0.0261	0.0686	0.0441	0.0105	0.0568	0.0033
Perlis	0.0571	0.0662	0.0667	0.0145	0.0547	0.0084	0.0062	0.0543	0.0716
P.Pinang	0.0000	0.0591	0.0519	0.0434	0.0403	0.0061	0.0104	0.0546	0.0105
Selangor	0.0394	0.0440	0.0000	0.0570	0.0473	0.0258	0.0014	0.0434	0.0057
Terengganu	0.0299	0.0587	0.0275	0.0313	0.0669	0.0190	0.0035	0.0538	0.0208
WPKL	0.0571	0.0403	0.0183	0.0502	0.0000	0.0000	0.0000	0.0000	0.0212

Appendix 4 : Climate Change Vulnerability Index (Cont')

Component	Social Vulnerability			Economic Vulnerability		Environmental Vulnerability
States	**Population**	**Dependency**	**Health**	**Poverty**	**GDP**	**Air Pollution**
Johor	0.0014	0.0447	0.0500	0.0077	0.0548	0.0000
Kedah	0.0017	0.0577	0.0595	0.0460	0.0667	0.0013
Kelantan	0.0007	0.0691	0.0669	0.0412	0.0746	0.0437
Melaka	0.0046	0.0445	0.0332	0.0000	0.0489	0.0000
N9	0.0011	0.0476	0.0474	0.0019	0.0445	0.0000
Pahang	0.0000	0.0406	0.0604	0.0153	0.0519	0.0437
Perak	0.0007	0.0526	0.0290	0.0288	0.0624	0.0013
Perlis	0.0025	0.0448	0.0532	0.0527	0.0636	0.0013
P.Pinang	0.0148	0.0331	0.0239	0.0067	0.0352	0.0013
Selangor	0.0064	0.0082	0.0504	0.0019	0.0385	0.0000
Tganu	0.0004	0.0303	0.0614	0.0335	0.0574	0.0437
WPKL	0.0692	0.0000	0.0000	0.0019	0.0000	0.0000