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EVALUATION OF WIND HAZARD OVER SABAH AND SARAWAK

FIONA ANAK GASING

Thesis submitted in fulfilment of the requirements
for the award of the degree of
B.Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2015

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Civil Engineering (Hons.).

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DEDICATION

This thesis is a symbol of appreciation for my beloved parents Mr. Gasing anak Nyalau and Madam Jong Moi Jin and my siblings, Felicia Bangkang, Felix and Foster,

AND

Thanks to my supervisor Mr. Noram I. Ramli, fellow course mates and friends for their constant assistance and support.

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest appreciation to my supervisor, En. Noram Irwan Bin Ramli for giving me his brilliant guidance, patience, valuable advices and enthusiastic encouragement throughout this study. The immense knowledge, valuable guidance and recommendation that he shared are highly appreciated. His unceasing and excellent supervision have assisted me to complete the project.

Apart from that, I would like to express my appreciation to all of the lectures in Universiti Malaysia Pahang whom have educated me in this past four years. They have undeniably helped me to reinforce my basic knowledge and theories in this Civil Engineering field course.

A special thanks also goes to my friends, Bong Kwong Nyap, Yap Yee Von, Steny Chin and Debbie Cynthia, for they are always willing to share their precious knowledge, resources and gave me a lot of helps and support throughout this study.

Most importantly, none of this would have been possible without the love and patience of my family. I would like to express my heart-felt appreciation to my family Mr Gasing anak Nyalau, Mdm Jong Moi Jin, Felicia Bangkang, Felix and Foster for their enthusiastic support and endless encouragement during my study.

ABSTRACT

Wind induce has become expressively reported widely in Malaysia. Numeral of study was conducted to mitigate and reduce wind risk in Malaysia. However most of the studies were conducted focusing to Peninsular Malaysia. There are very minimum information related to the wind characteristic in Sabah and Sarawak. Therefore this study was conducted to examined and evaluate the potential of wind risk in Sabah and Sarawak. Meteorological Data from meteorological station are used in directive to evaluate the wind storm risk in Sabah and Sarawak. Geographical Information System is used to evaluate the wind speed over Sabah and Sarawak. From the wind speed map produced, it shows those wind speed tendencies are periodically repeated anually for both state. The monsoon wind devided into two seasonal which called southwest monsoon between May to September and northeast between November to Mac. Frequent strong wind was observed during the southwest monsoon. This result shows opposite characteristic compare to the Peninsular Malaysia where the higher wind speed recorded during the Northeast Monsoon. This study also identify that damage occured in Sabah are significantly related to the monsoon season where numbers of damage is highly reported during this period. However in Sarawak there are lower significant relationship between the damage occured and the monsoon season. The damage were reported highly during the inter change of the monsoon season. During the inter change monsoon localised thunderstorm were frequently occured. Therefore the wind induce damage in Sarawak are significantly due to the micro scale event rather than seasonal monsoon wind. From all the result obtain, it can be conclude that wind characteristic is differs from place to place. Consequently, the wind risk is influenced by the geographical position at the specific location. Furthermore all consideration due to wind mitigation used in Peninsular Malaysia cannot simply consider in Sabah and Sarawak.

ABSTRAK

Sejak akhir ini bencana angin dilaporkan secara meluas di Malaysia. Beberapa kajian telah dijalankan untuk mengurangkan risiko angin di Malaysia. Walau bagaimanapun, kebanyakan kajian telah dijalankan memberi tumpuan kepada Semenanjung Malaysia sahaja. Ciri-ciri angin di Sabah dan Sarawak dan maklumat yang berkaitan adalah sangat minimum. Oleh itu kajian ini dijalankan untuk mengkaji dan menilai potensi risiko angin di Sabah dan Sarawak. Data dari meteorologi dari stesen meteorologi digunakan dalam arahan untuk menilai risiko ribut angin di Sabah dan Sarawak. "*Geographical Information System*" digunakan untuk menilai kelajuan angin di Sabah dan Sarawak. Dari peta kelajuan angin yang dihasilkan, ia menunjukkan kecenderungan kelajuan angin secara berkala berulang secara tahunan untuk kedua-dua negeri. Angin monsun dibahagikan kepada dua bermusim yang dipanggil monsun barat daya di antara bulan Mei hingga September dan timur laut antara bulan November hingga Mac. Angin kencang kerap diperhatikan semasa monsun barat daya. Keputusan ini menunjukkan ciri-ciri yang bertentangan berbanding dengan Semenanjung Malaysia di mana kelajuan angin yang lebih tinggi yang dicatatkan pada Monsun Timur Laut. Kajian ini juga mengenal pasti kerosakan yang berlaku di Sabah adalah lebih signifikan dengan musim barat daya di mana banyak nombor kerosakan telah dilaporkan dalam tempoh ini. Namun di Sarawak tiada hubungan yang signifikan diantara musim monsoon dan kerosakan yang berlaku. Kerosakan yang dilaporkan ketika perubahan yang ketara di monsun. Semasa perubahan di antara monsun, ribut petir yang kerap berlaku di bahagian Sarawak. Oleh itu, kerosakan di Sarawak adalah didorong oleh kejadian yang berskala mikro. Dari semua hasil yang diperolehi, boleh membuat kesimpulan bahawa sifat angin adalah berbeza dari tempat ke tempat. Oleh itu, risiko angin ialah dipengaruhi oleh kedudukan geografi di lokasi yang tertentu. Tambahan pula semua faktor yang digunakan di Semenanjung Malaysia tidak boleh digunakan sama sekali di Sabah dan Sarawak.

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LIST OF SYMBOLS

V_s	Basic Wind Speed
X_T	Recurrent Interval Year
X	Wind Speed
T	Year
F	Force
m	Mass
ρ	Density
a	Acceleration
V	Velocity
q	Static Pressure
m/s	Meter per Second
M_d	Direction Multiplier
$M_{z,cat}$	Terrain Height Multiplier
M_s	Shielding Multiplier
M_h	Hill Shape Multiplier
P_s	Wind Pressure
C_{fig}	Aerodynamic Shape Factor
C_{dyn}.	Dynamic Response Factor

LIST OF ABBREVIATIONS

UN	United Nation
GIS	Geographical Information System
MS	Malaysian Standard
ISO	International Organisation for Standardisation
ASCE	American Society of Civil Engineers
AIJ	Architectural Institute of Japan
AS	Australia Standard
BS	British Standard
NBCC	National Building Code of Canada
IDW	Inverse Distance Weighted

CHAPTER 1

INTRODUCTION

1.1 AN OVERVIEW OF WIND HAZARD

Wind is a natural phenomenon, where the speed of the wind cannot be control by human. Extreme wind is one of the major natural hazards experienced on earth. Wind is caused by temperature gradient of the atmosphere.

Wind Formation is a wind form when warm air expands and rises up while cold air condenses and sinks hence resulting the flow of air. The state of air differentiate between regions as the earth is affected by an unequally of heat energy from sun. The vertical component the wind is generally small except in thunderstorm updrafts. The air can move along a vertical or horizontal axis. When large quantities of air move up along a vertical axis, the end result is cloud formation. By contrast, horizontally moving air results in wind. The direction of wind indicates from the direction of the wind is blowing and reported to one of the 16 points of the compass (N, NE, etc.) or 360 ° with reference to true north. There is several factors play an important role in the initial creation of wind as relative speed at which the wind flows. There are pressure gradient force, friction and coriolis force. Wind Speed can be known as wind flow velocity as a fundamental atmospheric rate. The air moving from high pressure to low pressure causing wind speed to occur due to changes in temperature. Wind speed is the rate of the motion of air in a unit of time and measured in meter per second (m/s), knots and kilometer per hour (km/h). Wind speed measured with an anemometer. Ananemometer has four cups that can more accurately measure wind speed instead of measuring which direction the wind is blowing with pointers. Factors that affecting the wind speed are the pressure gradient is the first.

The second is friction caused by air flowing over the ground, trees, buildings, etc. Friction explains why wind doesn't flow perfectly circular around lows and highs, because if it was not for friction the pressure gradient force would be balanced by the coriolis force and remain at a constant distance from the center of the high or the low once a balance was established.

Unfortunately, extremely strong wind can causes property damage even loss of life. Some part of Malaysia in every year will expected of damages caused by the wind hazard. The damages will effect either to properties, environment and human .Every losses caused by a typical damage value reach from thousand to a million ringgit.

Wind related disaster is classified as one of the dangerous disaster by United Nation (UN). The yearly variation of the number of devastating natural disasters as shown in Figure 1.1. From this figure, it is observed that the second highest number of reported disasters was storms as compared to other weather-related events such as floods and droughts.

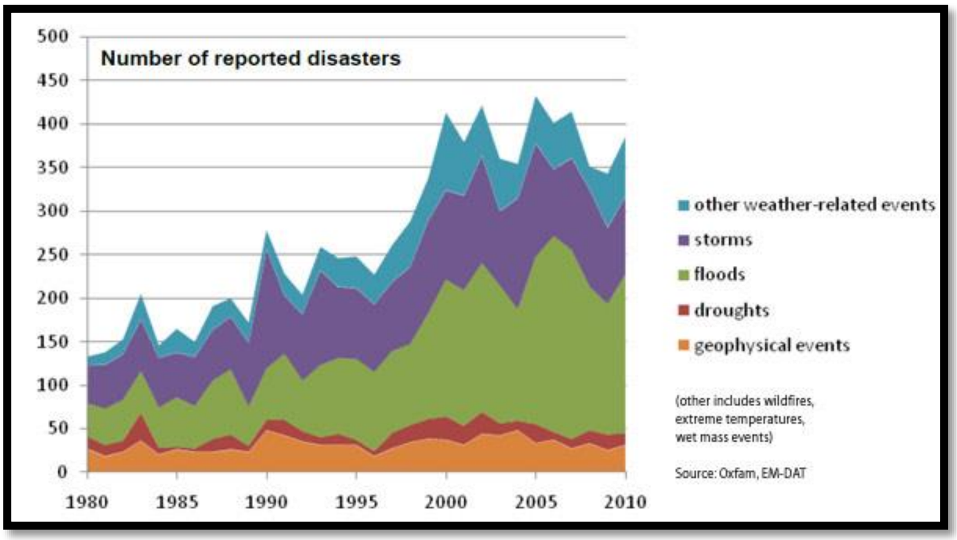


Figure 1.1: Yearly Variation of the Number of Devastating Natural Disasters

Source: Oxfam, EM_DAT

Some of the serious wind hazard cases happened in most recent years at Sarawak and Sabah were summarized as shown in Table 1.1.

Table 1.1: Wind hazard cases happened in Sarawak and Sabah

Place	Date	Damage
Kuching	October 2, 2013	4 coffee shops Some houses
	June 17,2014	20 houses 1 death 1 car
Bintulu	September 21, 2013	10 houses 4 vehicles
Miri	October 9, 2014	1 mosque 8 houses 1 school
	October 19,2014	Some houses Public properties Some Vehicles
Sibu	July 1, 2013	20 houses
Keningau	September 19, 2014	49 houses
Kota Kinabalu	July 16, 2013	Some houses 2 vehicle Public properties

1.2 PROBLEM STATEMENT

Wind induce has become expressively reported widely in Malaysia. Numeral of study was conducted to mitigate and reduce wind risk in Malaysia. However, most of the studies were conducted focusing to Peninsular Malaysia. There are very minimum information related to the wind characteristic in Sabah and Sarawak. For Sabah and Sarawak, there are no specific investigation and information on wind hazard disaster. Besides that, there are no specific investigation conduct by any researchers in Sabah and Sarawak. Currently, high percentage of wind related disasters especially in Sabah and Sarawak. High wind speed can causes more damages and increase risk to human life.

1.3 OBJECTIVE OF STUDY

The main purpose of this study is to evaluate the wind hazard over Sabah and Sarawak. In achieving the outcomes outlined above, the research objectives are briefly summarized below.

1. To develop the wind hazard map in Sabah and Sarawak by using Geographical Information System (GIS) software.
2. To investigate the wind induced damage by geographical location.

The number of occurrence and level of damage are shown in Figure 1.2, Figure 1.3 and Figure 1.4.

Figure 1.2 Damaged in Sibu

Source: Borneo Post, 2013

Figure 1.3: Damage in Kuching

Source: Borneo Post, 2014

Figure 1.4: Damage in Bintulu

Source: Borneo Post. 2013

1.4 SCOPE OF STUDY

The field study is to evaluate of wind hazard over a particular location. In this study, the area of study is limited to Sabah and Sarawak only. Meteorological data from meteorological station are used in directive for evaluation of wind storm risk in Sabah and Sarawak.

At the end, the wind hazard map in Sabah and Sarawak are established by using Geographical Information System (GIS) software ArcGIS 9 Version 9.2. ArcGIS software database that completed with location of weather stations and wind speed are established.

1.5 STUDY AREA

The study area is limited to Sabah and Sarawak only in Figure 1.5. The peninsular of Malaysia is not included in this study.

Figure 1.5: Sabah and Sarawak Map

1.6 SIGNIFICANT OF STUDY

This study is to evaluate the wind hazard in Sabah Sarawak. This research also included the investigation on the wind induces damage by geographical location. The reason for this research study is because of the lack of information regarding to the wind hazard in Sabah and Sarawak. Due to the lack of information of wind in Sabah and Sarawak, the public are less aware of the risk of wind events which could greatly impact* on their life if not taken seriously. Thus, this research study is to. A significant amount of database is needed in order to mitigate any kind of hazard risk posed by wind hazard. This study also was able to produce the wind hazard map as a given guideline in Sabah and Sarawak for future prevention.

1.7 THESIS STRUCTURE

This thesis is divided into five chapters as shown in Table 1.2.

Table 1.2: Thesis structure

Chapter	Content	Description
1	Introduction	This chapter includes overview of problem statement, objective and scope of the study, significant of study and study area.
2	Literature review	This chapter is the previous study material related to objectives.
3	Methodology	The flow of thesis production using Geographical Information System (GIS) software.
4	Discussion	Discuss the result obtained based on case study.
5	Conclusion	Conclusion of the discussion based on thesis result and provides the system (GIS) software.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Wind is moving air or identified as perceptible natural movement of air. Wind caused by differences in air pressure within our atmosphere. Air under high pressure moves toward areas of low pressure. The greater the difference in pressure, the faster the air flows. This chapter will present the review on literature review study on winds in Malaysia, basic wind speed, wind force, design wind speed, wind hazards, and Geographical Information System.

2.2 WINDS IN MALAYSIA

Malaysia is a country that located at Southeast Asia which deals with the tropical climate of Malaysia. Malaysia is divided into two distinct parts which called as West Malaysia and East Malaysia. From Figure 4, for West Malaysia or can be called as Peninsular Malaysia is located at south of Thailand, east of Indonesian island of Sumatra and north of Singapore. West Malaysia is sharing borders with Thailand, Indonesia and Singapore. After that, for East Malaysia or can be called as Borneo is comprises most of northern part and shares borders with Indonesia, Brunei and Philippines.

Winds are generally light form of atmosphere. Malaysia characteristic features can be known as a uniform temperature, high humidity and over rainfall. According to Malaysian Meteorological Department, exceptionally rare situation to have an extend of a few days that a full day with entirely clear sky and also can be exceptionally rare situation few days with no sunshine except during monsoon seasons.

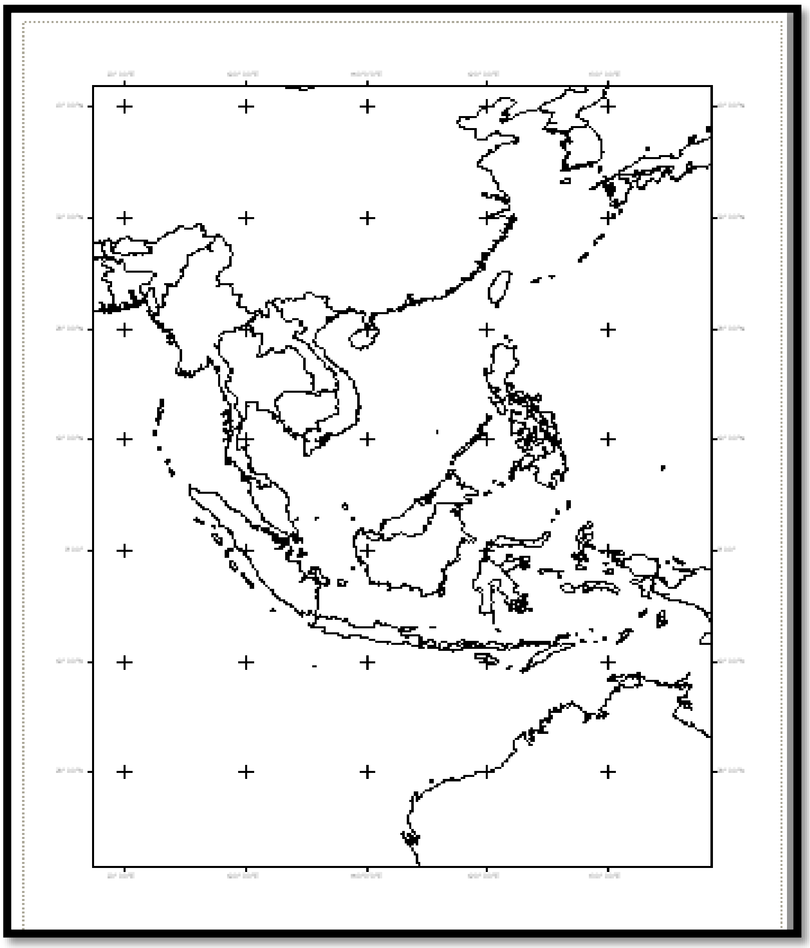


Figure 2.1: South East Asia Regional Map

Source: Malaysia Country Report, 2010

2.2.1 WIND CHARACTERISTIC IN WIND FLOWS

There are different patterns of wind flows of each country. This is depends on the equatorial position. Generally, wind over country normally light and variable, conversely some consistent periodic changes in wind flow patterns. There are four seasons in Figure 2.2 can be distinguished based on the changes, specifically as southwest monsoon, northeast monsoon, and 2 shorter periods of inter-monsoon season.

The time period for southwest monsoon season to establish is in the latter half of May or early June and will ends in September. The usually wind flow is below 15 knots under this monsoon season. The northeast monsoon season to establish is in the early of November and ends in March. The usually wind flow is between ranges of 10 to 20 knots. However, winds over the east coast states of Peninsular Malaysia May reach 30 Knots or more during this periods of strong surges of cold air from north (cold surges). For the two inter-monsoon seasons, the winds are normally light and variable, for that reason of the equatorial trough lies over Malaysia. Time period of inter- monsoon season to establish is during a month of April and October. In Sarawak, there are more localized thunderstorms during southwest monsoon which lower significant to that monsoon.

Monsoon is caused by land-sea temperature differences due to heating by the sun's radiation. In winter, the continental landmass cools rapidly resulting in extremely low temperatures over central Asia. When temperature drops, atmospheric pressure rises and an intense high pressure system (anticyclone) develops over Siberia. Cold air flows out of Siberia as northwester lies and turns into northeaster lies on reaching the coastal waters of China before heading towards Southeast Asia.

From time to time, strong outbursts of cold air (termed as monsoon surges) interact with low pressure atmospheric systems and cyclonic vortices are formed near the equator resulting in strong winds and high seas in the South China Sea and heavy rainfall to east coast states of Peninsular Malaysia as well as the west coast of Sarawak in East Malaysia. In summer, intense solar heating leads to scorching temperatures over the Asian landmass. As hot air expands and rises upwards, a semi-permanent low-pressure area develops. Moist southeaster lies originating from the southern Indian Ocean and the Indonesian-Australian region transforms into southwester lies on crossing the equator and flow across Southeast Asia before converging towards Indochina, China and Northwest Pacific. The approaching wind characteristics are largely controlled by the roughness of the upwind fetch over which it had blown. (Choi, 2009)

Typhoons frequently develop over west pacific during the early month April to November. This will lead to move across westwards regions of Philippines and south westerly winds over the northeast of Sabah and Sarawak region may be up or more to 20 knots during that time.

Figure 2.2 Malaysia Wind Map

Source: http://durianinfo.blogspot.com/p/durian-seasons-in-durian-production.html

2.3 BASIC WIND SPEED

Basic wind speed (V_s) can be defined as maximum wind speed that will occur one in a recurrent interval year (X_T), where X is the wind speed and T is year. Therefore, for T year it always taken as 50 years and 100 years. All meteorological stations are using the same reference the basic wind speed, Vs at 10 m height from ground level. Hence, that will be considered in the step of calculation design load for building structure. Basic wind speed is based on averaging time 10 minute to 1 hour for some several international codes and standards, (Zhou and Kareem, 2002). In some cases averaging time is taken as 3 second as listed in Table 2.1 below. Averaging time is wind speed measured over an interval time to provide basic wind speed.

Table 2.1: Time Average of Basic Wind Speed

Country	Code	Time Average
-	ISO 4354	10 minutes
European Country	ENV 1991-2-4	10 minutes
United States Of America	ASCE 7-98	3 seconds
Japan	AIJ 1996	10 minutes
Australia	AS 1170.2	3 seconds
United Kingdom	BS 6399: Part 2	1 hour
Canada	NBCC 1996	1 hour
Malaysia	MS 1553:2002	3 seconds

Design wind speed is derived from site wind speed multiplied with some parameter such as terrain categories and type of building. The design wind speed is used in deriving the wind loads or also known as equivalent static wind load. Reviewing on MS 1553: 2002, some historical reasons that there was many Foreign Standards used for Malaysian Construction works.

Malaysia is using Malaysia Standard. MS 1553: 2002 Wind Load for Building Structure presently. There are still many studies carry out to improve and update the code from time to time especially to improve the coefficient factor based on local climate and our widespread material that been used in Malaysia.

2.4 WIND FORCE

Static wind load needed the most in connection with stress calculations and design because natural frequency of building to category i.e. and majority is not more than 1.0 hertz (Dybre and Hansen, 1996) Newton first law says that Force can calculated from mass and acceleration as,

$$F = ma \tag{2.1}$$

where, m (mass) is equal to volume x density (ρ) and a, acceleration is equal to changing wind speed over an interval of time. From equation 2.1, it is relates between wind speed and force. Another equation gives more accurate assumption in calculation f static wind load introduced by Bernoulli.

$$p + 0.5\ \mathrm{p}{V_s}^2 = 0 \tag{2.2}$$

where p is sum of static pressure, ρ is air density and V is velocity. This equation is called *hyrodynamica*, which specifies that the sum of static pressure, p and the velocity pressure, $0.5\rho V_s^2$is constant along streamline. From equation 2.2 design wind speed pressure can be measured by:

$$q = 0.5\ \mathrm{p}{V_s}^2 \tag{2.3}$$

Equation 2.3 has been used until now as a guideline to calculate static pressure from basic wind speed. Equation 2.3 also has also been adopted ISO 4354 as a guideline for drafting national codes of practice.

2.5 DESIGN WIND SPEED

The basic wind speed V_s must be obtained in order to calculate the design wind pressure on building. Basic wind speed for 30 cities in Malaysia has been provided in MS 1553:2002 as listed in Table 2.2.

Table 2.2: Basic Wind Speeds for Major Cities in Malaysia MS 1553:2002 for Various Return Period (MS1553:2002)

Station	20 years return period (m/s)	50 years return period (m/s)	100 years return period (m/s)
Chuping	23.8	25.6	27.0
Alor Setar	27.2	29.9	31.8
Bayan Lepas	25.6	27.5	28.9
Butterworth	24.6	26.4	27.7
Ipoh	30.6	33.5	35.7
Sitiawan	23.3	25.3	26.7
Batu Embun	25.3	27.5	28.9
Cameron Highlands	25.2	26.8	28.0
Subang	29.2	32.1	34.3
Petaling Jaya	28.8	31.4	33.4
Melaka	26.7	29.4	31.3
Kluang	29.6	32.6	34.9
Senai	26.9	29.1	30.7
Mersing	29.5	32.0	33.8
Muadzam Shah	22.6	24.4	25.8
Temerloh	25.1	27.4	29.1
Kuantan	27.5	29.8	31.6
Kuala Terengganu	25.5	27.2	28.5
Kota Bahru	30.0	32.4	34.2
Kuala Krai	27.2	29.5	31.3
Kota Kinabalu	28.3	30.5	32.2
Kudat	27.1	29.1	30.6
Tawau	24.6	26.6	28.1
Sandakan	23.4	25.8	27.7
Labuan	26.0	27.7	29.0
Kuching	29.5	32.6	34.9
Miri	26.9	29.0	30.5
Sri Aman	27.6	30.3	32.4
Sibu	27.0	29.3	31.0
Bintulu	23.9	25.6	26.9

Note: - The basic wind speed is the 3-second gust speed estimated to be exceeded on the average once in a year at 10 meter heights. It should be assumed that wind may be from any horizontal direction.

After the value of V_s has been determined, the value of site wind speed, V_{site} can be calculated. In order to calculate V_{site}, basic wind speed V_s is multiplied by factors which are given in equation below:

$$V_{site} = V_s (M_d)(M_{z,cat})(M_s)(M_h) \quad (2.4)$$

where M_d is direction multiplier, $M_{z,cat}$ is terrain height multiplier, M_s is shielding multiplier and M_h is hill shape multiplier.

The calculation of design wind speed can be obtained by multiplying the value of site wind speed to the important factor *I*. Important factor *I* depends on the type of building structure usage. Table 2.3 illustrates the category of structures that have been incorporated in MS 1553:2002.

Table 2.3: Importance Factor *I* (MS 1553:2002)

Nature Of Occupancy	**Category of Structure**	***I***
Buildings and structures that represent low hazard to human life in the event of failure such as agricultural facilities, temporary facilities and minor storage facilities.	I	0.87
All building and structure except those listed in category I, II, III and IV	II	1.0
Buildings and structures where the primary occupancy is one in which more than 300 people congregate in one area	III	1.15
Essential buildings and structures Hospital and medical facilities Fire and police stations, Defense Shelter Structures and equipment in civil defense Communication centers and other emergency utilities	IV	1.15

The design wind pressures which can be calculated from equation (2.5).

$$P_s = 0.5\rho_{air} V_{des}^2 C_{fig} C_{dyn} \quad (2.5)$$

This equation gives pressure in unit Pascal. The design wind pressure is governed by the aerodynamic shape factor C_{fig} and the dynamic response factor, C_{dyn}.

2.6 WIND HAZARD

Wind hazard damage is natural disaster that caused by wind. Natural disaster such as hazard wind storm including cyclones, hydro-meteorologal, hurricanes and typhoons contributes to the percentage of damages all around the world (Bosher, 2008).

Wind induce damage to buildings and structures are regularly happen in Malaysia is because due to thunderstorm (Majid, 2010). Several studies have been made by some researchers about several factors that found on contribution of damage to building component. Most of the failures are with the lack of consideration due to wind effect during design stage.

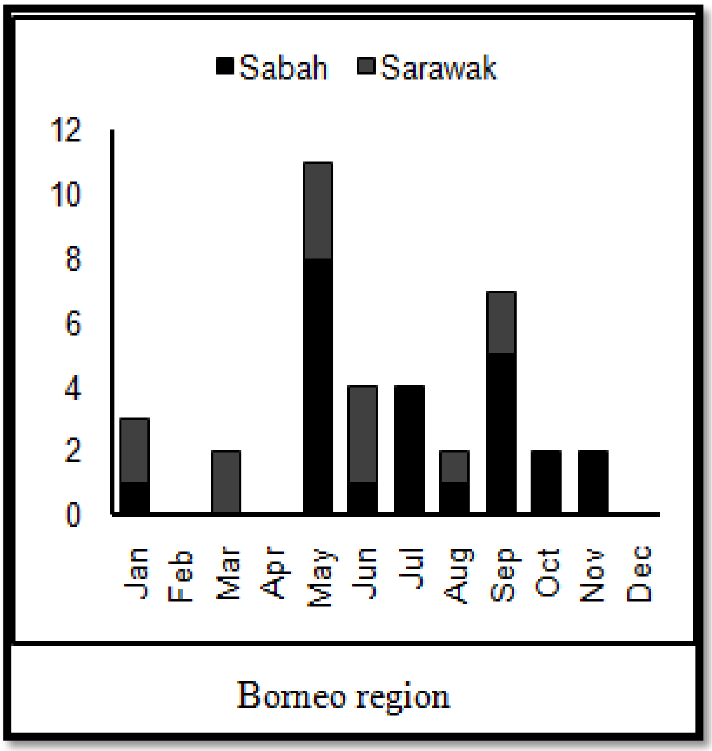


Figure 2.3: Frequencies of windstorms in Malaysia, 2000 – 2012 and annual temperature

Source: Annual temperature – *Department of Statistics Malaysia*, *2007 – 2011*

Trend in Figure 2.3 shows that monsoon is a significant factor that influences to the occurrences of the windstorm in Malaysia since the highest frequency month that recorded in all the regions is during monsoon. From the figure above, highest on May in Borneo region is during the southwest monsoon period which from May to September while Center region which located at the location that has high possibility of interaction between northeast monsoon and southwest monsoon recorded April which is in period of inter-monsoon. The first inter-monsoon (April) period is a season that most likely windstorm will occur, followed by southwest monsoon and northern monsoon. Thunderstorms occur throughout the year but are most likely to happen in the inter-monsoon periods.

2.7 GEOGRPHICAL INFORMATION SYSTEM

Geographical Information System (GIS) is a science and technology, a discipline and an applied problem solving methodology (Longley, 2005). GIS is concerned with the explanation, description and prediction of patterns and at the same time processes at geographic scales.

GIS consists of computer system and software, spatial data, data management and analysis procedure and people. This is to ensure the success of GIS. GIS software gives you the tools to detect the risk and gives idea of an action that need to be done in your experiment. GIS helps in future planning by mapping and analysis and it is capable to analyze hazard and predict the potential damage that will occur. For example, when the hazard is can be identify from mapping, future planning can be done for future prevention. Hence, strategic plan can be obtain by using GIS. GIS technology is builds and enhances emergency preparedness for world.

For data management in GIS, all information must be gathered to achieve comprehensive and preparedness. GIS is establishing full situational awareness by linking people, processes and information together using geography. Decision making based on analyzing the operating picture and resource management is for rapid development of emergency supplies, personnel and equipment also can be made.

Inverse distance weighted (IDW) interpolation determines cell values by using a linearly weighted combination of a set of sample points. The surface being interpolated should be that of a location dependent variable.

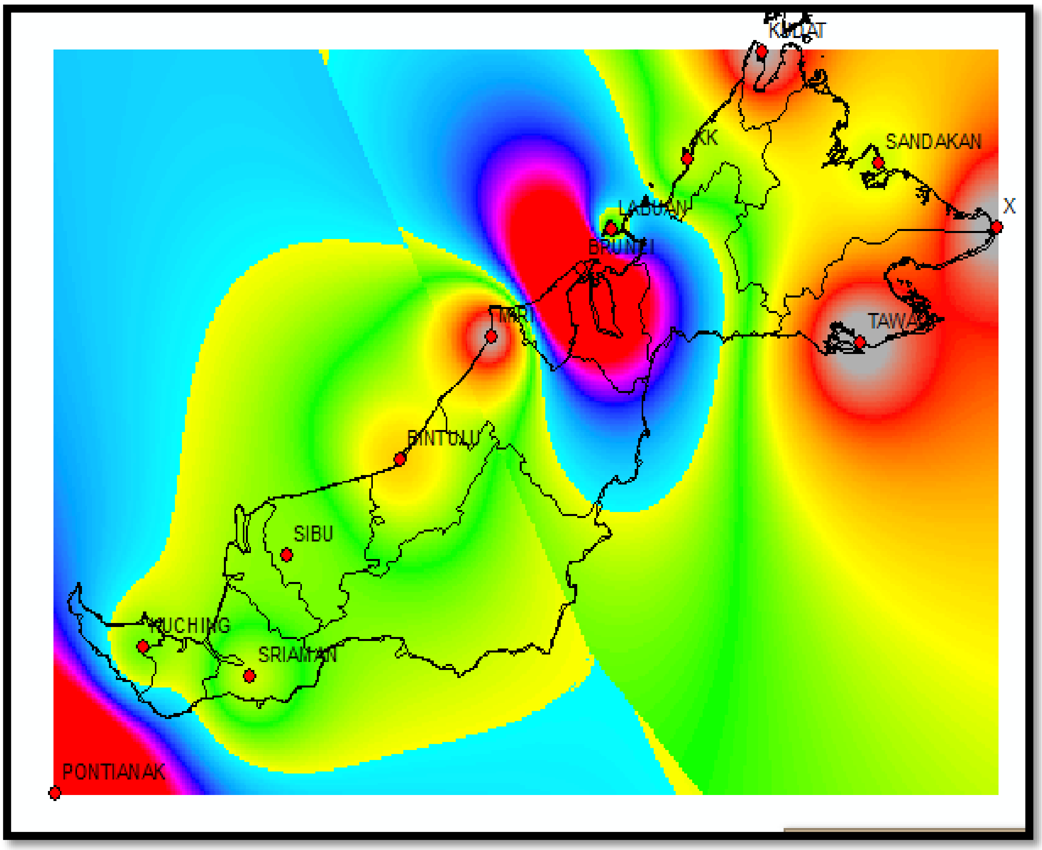


Figure 2.4: Inverse distance weighted (IDW) interpolation in Sabah and Sarawak

There are many applications in GIS software and brings a lot of benefit. GIS can be use to visualize spatial relationship and reveals trends critical to public safety planning and response. GIS were able to accomplish and analyzing the high amount of location based on information gathered. As a conclusion, GIS is the most suitable software to manage emergency, preparation and response and the ability to map and model the potential disaster. This preparation helps people to prevent from potential damages and the hazard consequences.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss the methodology that has been used in this study. The main purpose of this chapter is to obtain the objectives of this study. This study primarily consists of 4 phases, which are data collecting, pre-processing, processing and output.

I) Data collecting	: Wind hazard related cases in Sabah and Sarawak from 2013 to 2014 and wind speed of each area weather station.
II) Pre-processing	: Database to be converted in spatial interpolation using Geographical Information System (GIS).
III) Processing	: Establish data of wind speed and wind hazards cases.
IV) Output	: Wind hazards map and investigation of wind induced damage by geographical location.

Phase I, II and III are described in this chapter while Phase IV will be described in Chapter 4. The flow of the research methodology as shown in Figure 3.1.

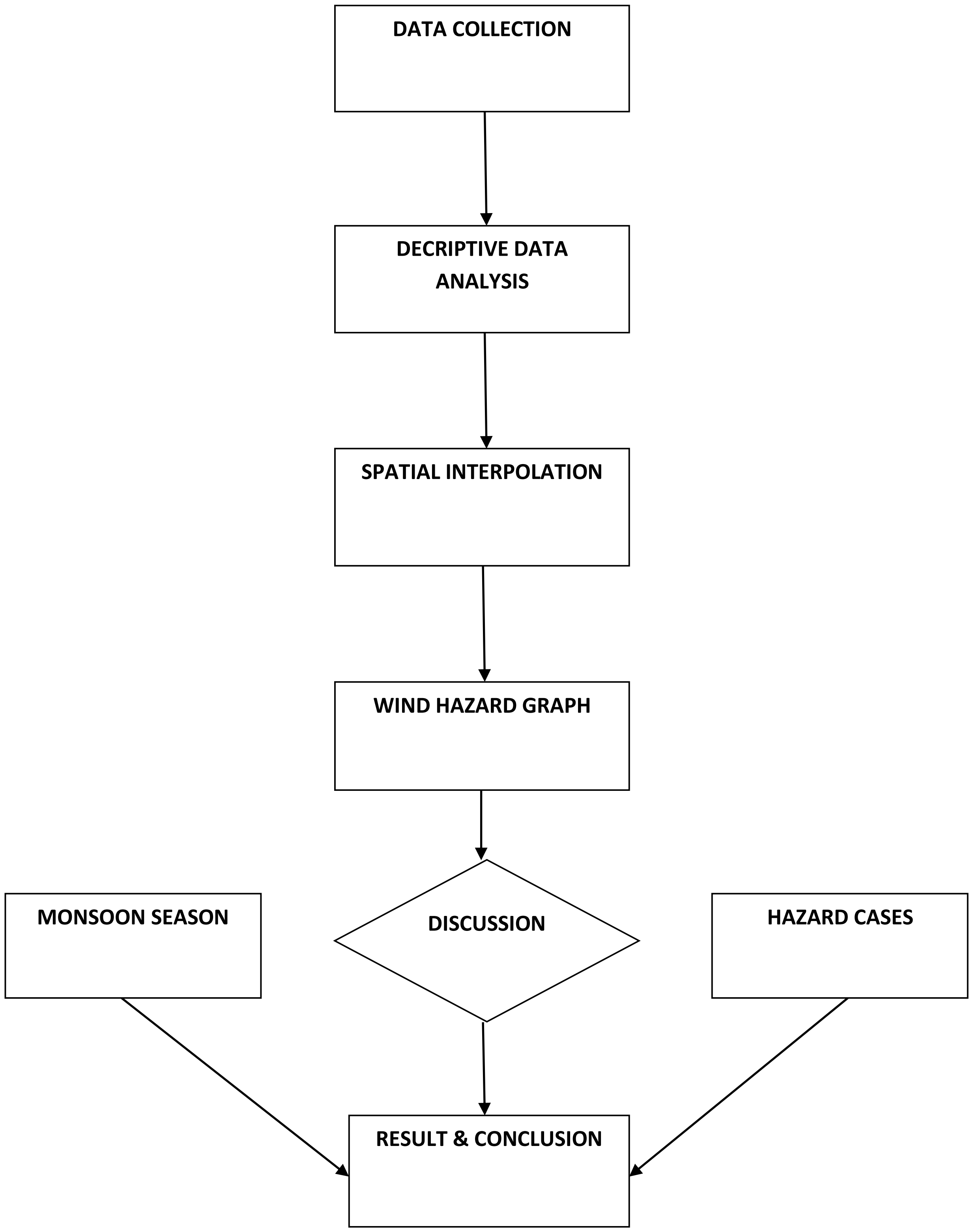


Figure 3.1: Research Methodology Flow

3.2 DATA COLLECTION

In this phase, this process of data collection is to gathered and measured the information on variables of interest of interest, an established systematic fashion that enable one to answer stated in research questions, test hypotheses, and evaluate outcomes. All the data collected are mainly from the Meteorological Station.

3.2.1 Wind Hazard Disaster Data

The wind hazard disasters were collected based on the year of 2013 to 2014. The data in use are place, date, damage type and losses were recorded in Microsoft Word for future references. A total of 8 cases were recorded from year 2013 to 2014 and Table 3.1 below is some of the wind hazard cases as an example:

Table 3.1: Wind Hazard cases

Place	Date	Damage
Kuching	October 2, 2013	4 coffee shops Some houses
	June 17,2014	20 houses 1 death 1 car
Bintulu	September 21, 2013	10 houses 4 vehicles
Miri	October 9, 2014	1 mosque 8 houses 1 school
	October 19,2014	Some houses Public properties Some Vehicles
Sibu	July 1, 2013	20 houses
Keningau	September 19, 2014	49 houses
Kota Kinabalu	July 16, 2013	Some houses 2 vehicle Public properties

3.2.2 Site Location Data

Site locations are specific on Sabah and Sarawak area only as mentioned in scope of study. A typical map for Sabah and Sarawak as shown in Figure 3.2. There are total of 10 weather forecast station, different location gives different longitude and latitude as shown in Table 3.2.

Figure 3.2: Site Location in Sabah and Sarawak

Table 3.2: 10 Location Coordinates

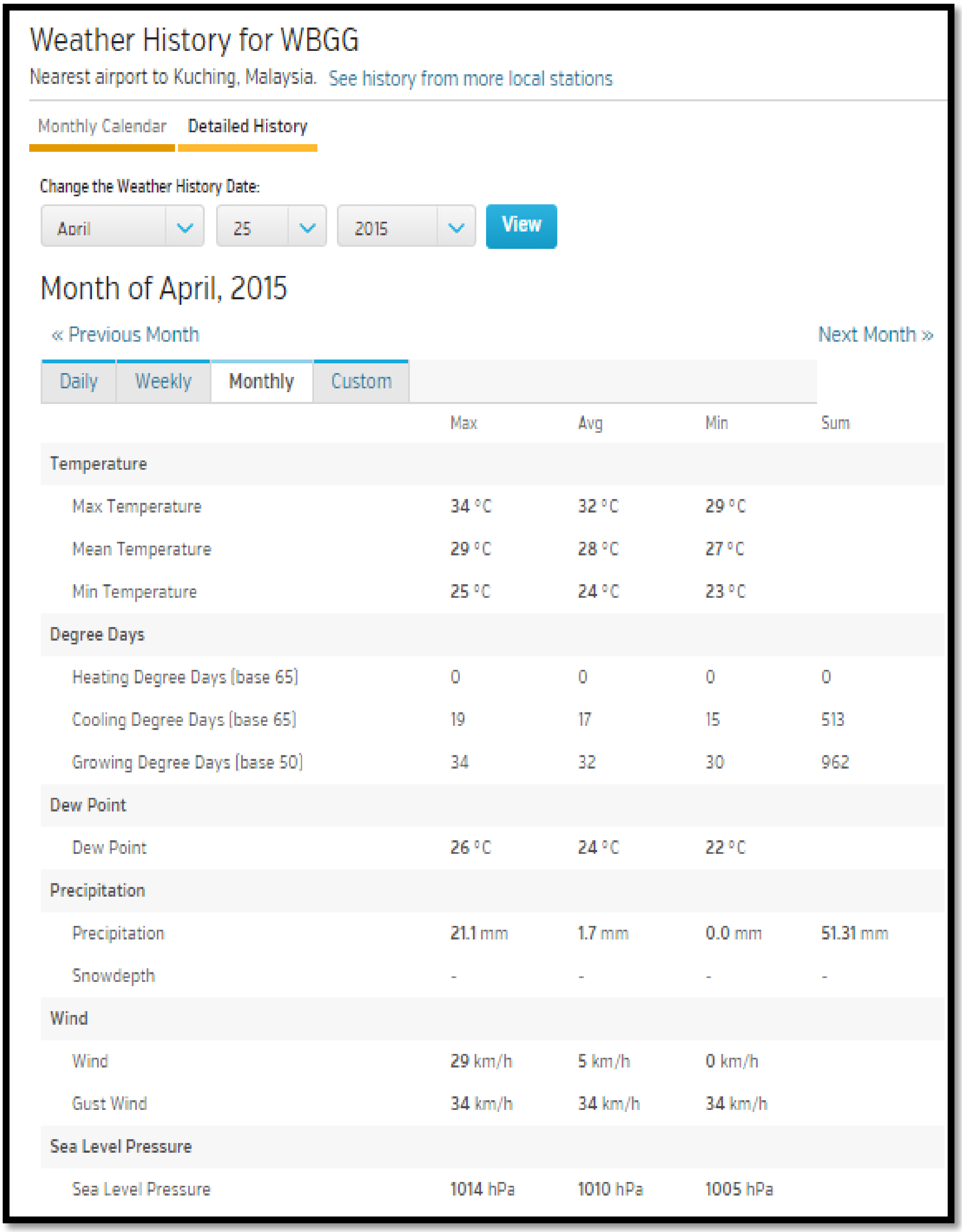
Location	Latitude (°N)	Longitude (°E)
Kuching	4.94	110.33
Sri Aman	1.22	111.45
Sibu	2.33	111.83
Bintulu	3.20	113.03
Miri	4.32	113.99
Labuan	5.30	115.25
Kota Kinabalu	5.94	116.05
Kudat	6.92	116.84
Sandakan	5.90	118.06
Tawau	4.27	117.88

The exact coordination are needed for each location are needed for ArcGis software which Latitude as X data and Longitude as Y data. This is extract to the right location position into the map.

3.2.3 Determine Wind Speed

Wind Speed is a fundamental atmospheric rate and is caused by moving air from high pressure to low pressure. Records of the monthly wind speed for 10 locations are from Meteorological Station starting from January 2013 to December 2014.

An example of weather history for a weather station located in Kuching, Sarawak, Malaysia on April 2013 is shown in Figure 3.3. An example of monthly weather history and observation also shown in Figure 3.4.



Weather History for WBGG

Nearest airport to Kuching, Malaysia. See history from more local stations

Monthly Calendar | Detailed History

Change the Weather History Date:

April | 25 | 2015 | View

Month of April, 2015

« Previous Month | Next Month »

Daily | Weekly | Monthly | Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	34 °C	32 °C	29 °C	
Mean Temperature	29 °C	28 °C	27 °C	
Min Temperature	25 °C	24 °C	23 °C	
Degree Days				
Heating Degree Days (base 65)	0	0	0	0
Cooling Degree Days (base 65)	19	17	15	513
Growing Degree Days (base 50)	34	32	30	962
Dew Point				
Dew Point	26 °C	24 °C	22 °C	
Precipitation				
Precipitation	21.1 mm	1.7 mm	0.0 mm	51.31 mm
Snowdepth	-	-	-	-
Wind				
Wind	29 km/h	5 km/h	0 km/h	
Gust Wind	34 km/h	34 km/h	34 km/h	
Sea Level Pressure				
Sea Level Pressure	1014 hPa	1010 hPa	1005 hPa	

Figure 3.3: Records of Meteorological Station

Daily Weather History & Observations

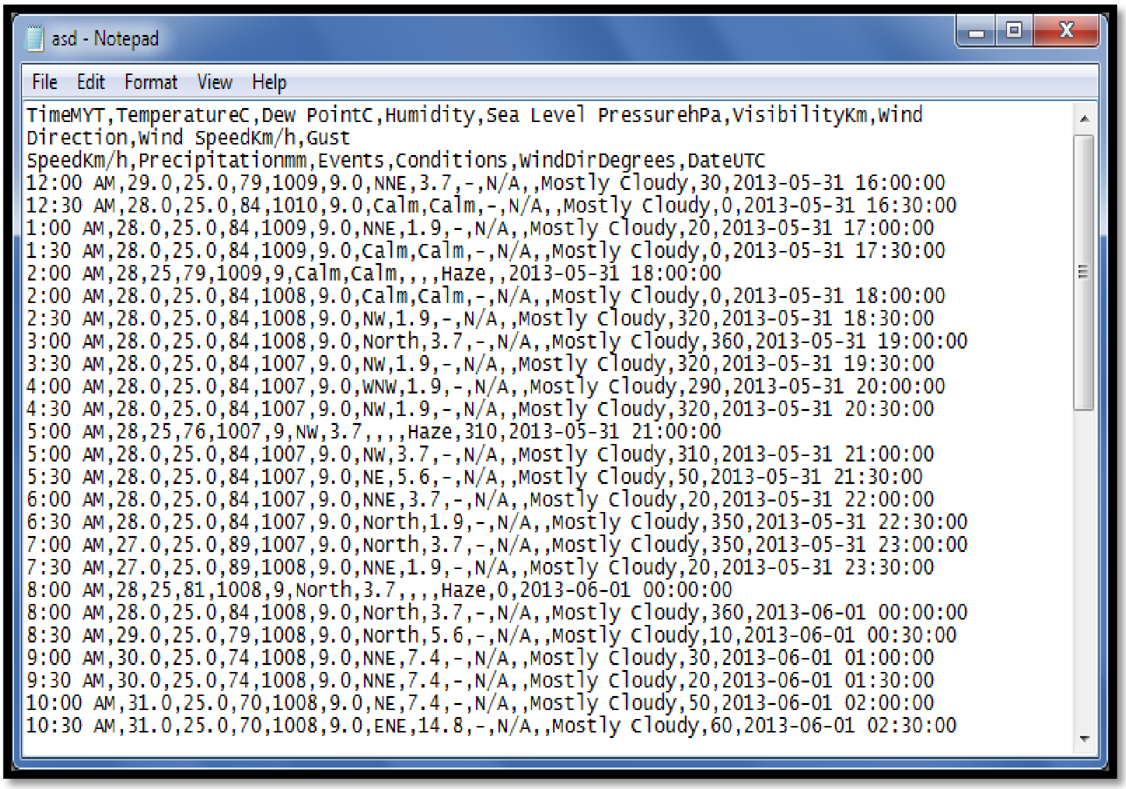
2015	Temp. (°C)			Dew Point (°C)			Humidity (%)			Sea Level Press. (hPa)			Visibility (km)			Wind (km/h)			Precip. (mm)	Events
Apr	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
1	33	29	25	25	24	23	94	84	59	1012	1010	1007	10	9	5	19	8	-	0.00	Rain , Thunderstorm
2	31	27	24	26	24	23	100	90	70	1012	1009	1006	10	8	0	16	5	-	0.00	Fog , Rain , Thunderstorm
3	32	28	24	26	24	22	100	85	66	1011	1009	1006	10	9	1	21	5	-	0.00	Rain
4	33	28	23	25	23	22	100	81	55	1010	1008	1005	10	10	10	16	5	-	0.00	
5	34	29	24	26	24	22	94	82	52	1011	1009	1005	10	10	3	19	6	-	0.00	Rain , Thunderstorm
6	32	28	24	26	24	23	94	83	59	1011	1009	1006	10	10	8	16	5	-	0.00	Rain
7	32	28	25	26	25	24	100	82	62	1010	1009	1006	10	10	10	19	6	-	0.00	Thunderstorm
8	31	27	23	26	24	22	100	84	70	1010	1009	1006	10	9	1	29	8	-	0.00	Rain , Thunderstorm
9	32	28	24	26	24	23	100	86	66	1012	1010	1008	10	9	3	23	6	-	0.00	Rain , Thunderstorm
10	33	28	23	25	24	23	100	87	59	1012	1010	1007	10	9	0	16	5	-	0.00	Rain , Thunderstorm
11	31	27	24	25	24	23	100	87	66	1013	1011	1008	10	10	4	21	5	-	0.00	Rain
12	31	27	24	26	24	23	100	87	70	1014	1012	1009	10	10	8	13	3	-	0.00	Rain
13	32	27	23	25	24	22	100	84	62	1014	1011	1008	10	10	10	13	3	-	0.00	
14	32	28	24	26	25	24	100	82	62	1012	1010	1006	10	10	6	16	5	-	0.00	
15	31	27	24	25	24	23	100	85	66	1013	1011	1009	10	10	3	16	5	-	0.00	Rain , Thunderstorm
16	33	28	24	26	24	23	94	83	59	1014	1012	1009	19	10	10	21	6	-	1.02	Rain , Thunderstorm
17	32	28	23	25	23	23	100	82	62	1013	1010	1007	26	11	10	16	6	34	0.00	Rain , Thunderstorm
18	33	28	23	26	24	23	100	81	56	1011	1009	1006	14	10	10	16	5	-	0.00	
19	33	28	24	26	24	23	100	82	50	1012	1010	1007	19	10	8	16	3	-	0.25	Rain
20	32	28	23	26	24	23	96	84	62	1013	1010	1007	14	10	10	13	5	-	0.00	
21	33	28	24	26	26	24	100	82	57	1011	1009	1007	11	9	6	14	3	-	0.00	
22	32	29	25	26	24	23	100	80	59	1011	1009	1007	14	9	6	19	6	-	0.00	
23	29	27	24	26	24	23	100	88	74	1012	1010	1008	11	10	8	16	3	-	1.02	Rain , Thunderstorm
24	33	28	23	26	24	23	100	84	52	1011	1010	1007	19	10	3	19	2	-	13.97	Rain
25	32	28	23	26	24	23	100	89	66	1012	1010	1007	14	10	3	19	3	-	4.06	Rain , Thunderstorm
26	33	28	23	25	23	22	100	80	51	1012	1010	1007	26	11	10	14	6	-	0.00	Rain
27	32	28	24	26	24	23	100	86	63	1012	1010	1007	19	9	5	21	5	-	9.91	Rain , Thunderstorm
28	33	28	23	26	24	23	100	84	60	1012	1010	1007	26	9	2	11	6	-	0.00	Rain , Thunderstorm
29	32	28	24	26	24	23	100	88	66	1012	1010	1008	26	10	1	16	5	-	21.08	Rain , Thunderstorm
30	33	28	23	26	24	23	100	86	56	1012	1010	1007	26	10	5	24	5	-	0.00	Rain , Thunderstorm

Comma Delimited File

Figure 3.4: Monthly weather history and observation

3.3 PRE PROCESSING

The data are taken from the www.wunderground.com as a comma delimited file then paste into a notepad as shown in figure below.



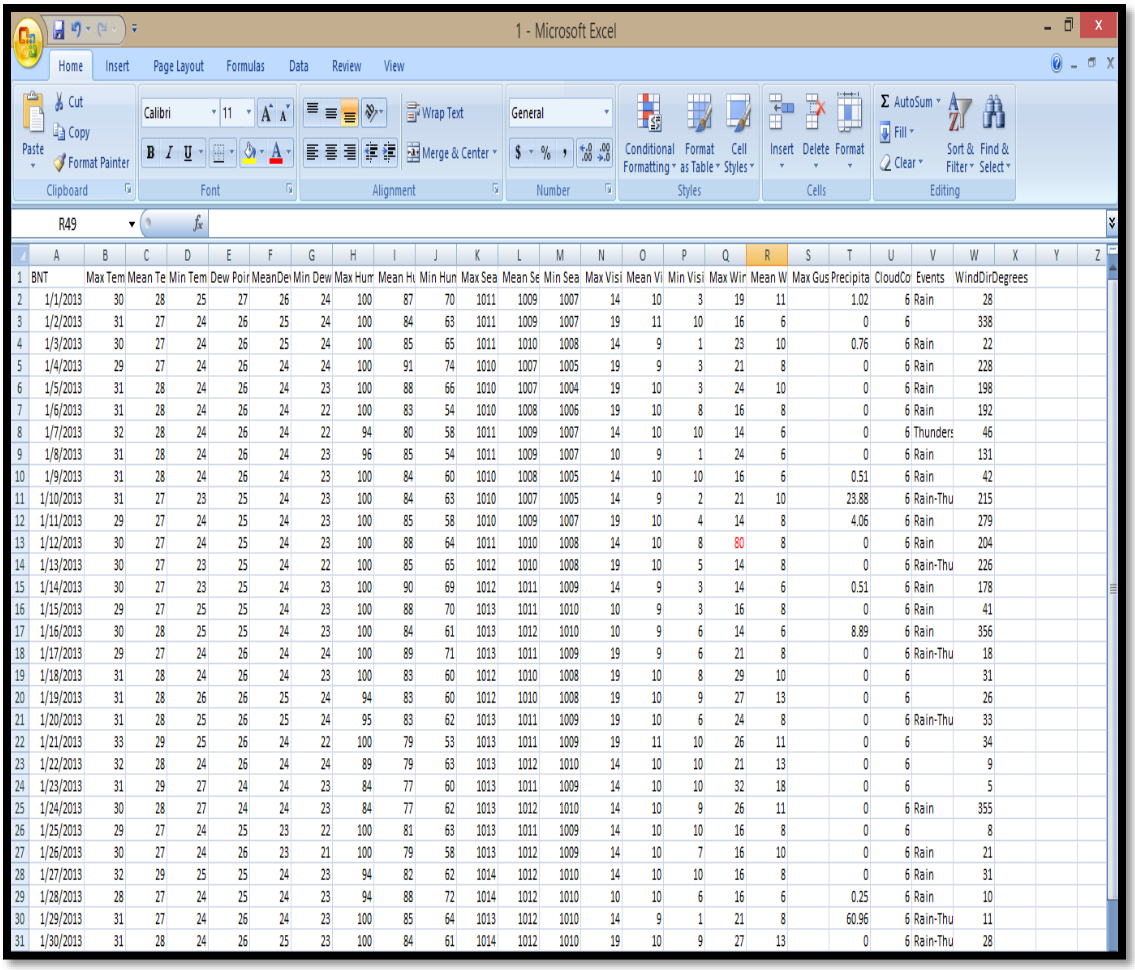
asd - Notepad

File Edit Format View Help

```
TimeMYT,TemperatureC,Dew PointC,Humidity,Sea Level PressurehPa,VisibilityKm,Wind
Direction,Wind SpeedKm/h,Gust
SpeedKm/h,Precipitationmm,Events,Conditions,WindDirDegrees,DateUTC
12:00 AM,29.0,25.0,79,1009,9.0,NNE,3.7,-,N/A,,Mostly Cloudy,30,2013-05-31 16:00:00
12:30 AM,28.0,25.0,84,1010,9.0,Calm,Calm,-,N/A,,Mostly Cloudy,0,2013-05-31 16:30:00
1:00 AM,28.0,25.0,84,1009,9.0,NNE,1.9,-,N/A,,Mostly Cloudy,20,2013-05-31 17:00:00
1:30 AM,28.0,25.0,84,1009,9.0,Calm,Calm,-,N/A,,Mostly Cloudy,0,2013-05-31 17:30:00
2:00 AM,28,25,79,1009,9,Calm,Calm,,,,Haze,,2013-05-31 18:00:00
2:00 AM,28.0,25.0,84,1008,9.0,Calm,Calm,-,N/A,,Mostly Cloudy,0,2013-05-31 18:00:00
2:30 AM,28.0,25.0,84,1008,9.0,NW,1.9,-,N/A,,Mostly Cloudy,320,2013-05-31 18:30:00
3:00 AM,28.0,25.0,84,1008,9.0,North,3.7,-,N/A,,Mostly Cloudy,360,2013-05-31 19:00:00
3:30 AM,28.0,25.0,84,1007,9.0,NW,1.9,-,N/A,,Mostly Cloudy,320,2013-05-31 19:30:00
4:00 AM,28.0,25.0,84,1007,9.0,WNW,1.9,-,N/A,,Mostly Cloudy,290,2013-05-31 20:00:00
4:30 AM,28.0,25.0,84,1007,9.0,NW,1.9,-,N/A,,Mostly Cloudy,320,2013-05-31 20:30:00
5:00 AM,28,25,76,1007,9,NW,3.7,,,,Haze,310,2013-05-31 21:00:00
5:00 AM,28.0,25.0,84,1007,9.0,NW,3.7,-,N/A,,Mostly Cloudy,310,2013-05-31 21:00:00
5:30 AM,28.0,25.0,84,1007,9.0,NE,5.6,-,N/A,,Mostly Cloudy,50,2013-05-31 21:30:00
6:00 AM,28.0,25.0,84,1007,9.0,NNE,3.7,-,N/A,,Mostly Cloudy,20,2013-05-31 22:00:00
6:30 AM,28.0,25.0,84,1007,9.0,North,1.9,-,N/A,,Mostly Cloudy,350,2013-05-31 22:30:00
7:00 AM,27.0,25.0,89,1007,9.0,North,3.7,-,N/A,,Mostly Cloudy,350,2013-05-31 23:00:00
7:30 AM,27.0,25.0,89,1008,9.0,NNE,1.9,-,N/A,,Mostly Cloudy,20,2013-05-31 23:30:00
8:00 AM,28,25,81,1008,9,North,3.7,,,,Haze,0,2013-06-01 00:00:00
8:00 AM,28.0,25.0,84,1008,9.0,North,3.7,-,N/A,,Mostly Cloudy,360,2013-06-01 00:00:00
8:30 AM,29.0,25.0,79,1008,9.0,North,5.6,-,N/A,,Mostly Cloudy,10,2013-06-01 00:30:00
9:00 AM,30.0,25.0,74,1008,9.0,NNE,7.4,-,N/A,,Mostly Cloudy,30,2013-06-01 01:00:00
9:30 AM,30.0,25.0,74,1008,9.0,NNE,7.4,-,N/A,,Mostly Cloudy,20,2013-06-01 01:30:00
10:00 AM,31.0,25.0,70,1008,9.0,NE,7.4,-,N/A,,Mostly Cloudy,50,2013-06-01 02:00:00
10:30 AM,31.0,25.0,70,1008,9.0,ENE,14.8,-,N/A,,Mostly Cloudy,60,2013-06-01 02:30:00
```

Figure 3.5: Comma Delimited File in Notepad

After that, the comma delimited file then insert into Microsoft Excel for a better view of a table data of the Comma Delimited File as shown in figure below.



BNT	Max Tem	Mean Te	Min Tem	Dew Poir	MeanDe	Min Dew	Max Hum	Mean Hu	Min Hun	Max Sea	Mean Se	Min Sea	Max Visi	Mean Vi	Min Visi	Max Wir	Mean W	Max Gus	Precipita	CloudCo	Events	WindDirDegrees
1/1/2013	30	28	25	27	26	24	100	87	70	1011	1009	1007	14	10	3	19	11		1.02	6	Rain	28
1/2/2013	31	27	24	26	25	24	100	84	63	1011	1009	1007	19	11	10	16	6		0	6		338
1/3/2013	30	27	24	26	25	24	100	85	65	1011	1010	1008	14	9	1	23	10		0.76	6	Rain	22
1/4/2013	29	27	24	26	24	24	100	91	74	1010	1007	1005	19	9	3	21	8		0	6	Rain	228
1/5/2013	31	28	24	26	24	23	100	88	66	1010	1007	1004	19	10	3	24	10		0	6	Rain	198
1/6/2013	31	28	24	26	24	22	100	83	54	1010	1008	1006	19	10	8	16	8		0	6	Rain	192
1/7/2013	32	28	24	26	24	22	94	80	58	1011	1009	1007	14	10	10	14	6		0	6	Thunders	46
1/8/2013	31	28	24	26	24	23	96	85	54	1011	1009	1007	10	9	1	24	6		0	6	Rain	131
1/9/2013	31	28	24	26	24	23	100	84	60	1010	1008	1005	14	10	10	16	6		0.51	6	Rain	42
1/10/2013	31	27	23	25	24	23	100	84	63	1010	1007	1005	14	9	2	21	10		23.88	6	Rain-Thu	215
1/11/2013	29	27	24	25	24	23	100	85	58	1010	1009	1007	19	10	4	14	8		4.06	6	Rain	279
1/12/2013	30	27	24	25	24	23	100	88	64	1011	1010	1008	14	10	8	80	8		0	6	Rain	204
1/13/2013	30	27	23	25	24	22	100	85	65	1012	1010	1008	19	10	5	14	8		0	6	Rain-Thu	226
1/14/2013	30	27	23	25	24	23	100	90	69	1012	1011	1009	14	9	3	14	6		0.51	6	Rain	178
1/15/2013	29	27	25	25	24	23	100	88	70	1013	1011	1010	10	9	3	16	8		0	6	Rain	41
1/16/2013	30	28	25	25	24	23	100	84	61	1013	1012	1010	10	9	6	14	6		8.89	6	Rain	356
1/17/2013	29	27	24	26	24	24	100	89	71	1013	1011	1009	19	9	6	21	8		0	6	Rain-Thu	18
1/18/2013	31	28	24	26	24	23	100	83	60	1012	1010	1008	19	10	8	29	10		0	6		31
1/19/2013	31	28	26	26	25	24	94	83	60	1012	1010	1008	19	10	9	27	13		0	6		26
1/20/2013	31	28	25	26	25	24	95	83	62	1013	1011	1009	19	10	6	24	8		0	6	Rain-Thu	33
1/21/2013	33	29	25	26	24	22	100	79	53	1013	1011	1009	19	11	10	26	11		0	6		34
1/22/2013	32	28	24	26	24	24	89	79	63	1013	1012	1010	14	10	10	21	13		0	6		9
1/23/2013	31	29	27	24	24	23	84	77	60	1013	1011	1009	14	10	10	32	18		0	6		5
1/24/2013	30	28	27	24	24	23	84	77	62	1013	1012	1010	14	10	9	26	11		0	6	Rain	355
1/25/2013	29	27	24	25	23	22	100	81	63	1013	1011	1009	14	10	10	16	8		0	6		8
1/26/2013	30	27	24	26	23	21	100	79	58	1013	1012	1009	14	10	7	16	10		0	6	Rain	21
1/27/2013	32	29	25	25	24	23	94	82	62	1014	1012	1010	14	10	10	16	8		0	6	Rain	31
1/28/2013	28	27	24	25	24	23	94	88	72	1014	1012	1010	10	10	6	16	6		0.25	6	Rain	10
1/29/2013	31	27	24	26	24	23	100	85	64	1013	1012	1010	14	9	1	21	8		60.96	6	Rain-Thu	11
1/30/2013	31	28	24	26	25	23	100	84	61	1014	1012	1010	19	10	9	27	13		0	6	Rain-Thu	28

Figure 3.6: Comma Delimited File in Microsoft Excel

3.4 PROCESSING

In term of processing, the map is produced by using Geographical Information System (GIS). Detailed procedures are presented in the following section.

3.4.1 Produce Map Using Geographical Information System (GIS)

Step 1

The collected databases are established in this phase. Firstly, the locations of weather stations are matched based on the coordination in Microsoft Excel and then inserted in the Geographical Information System (GIS) map based on the longitude and latitude in figure below. The figure below shows the location of the Penang International weather station.

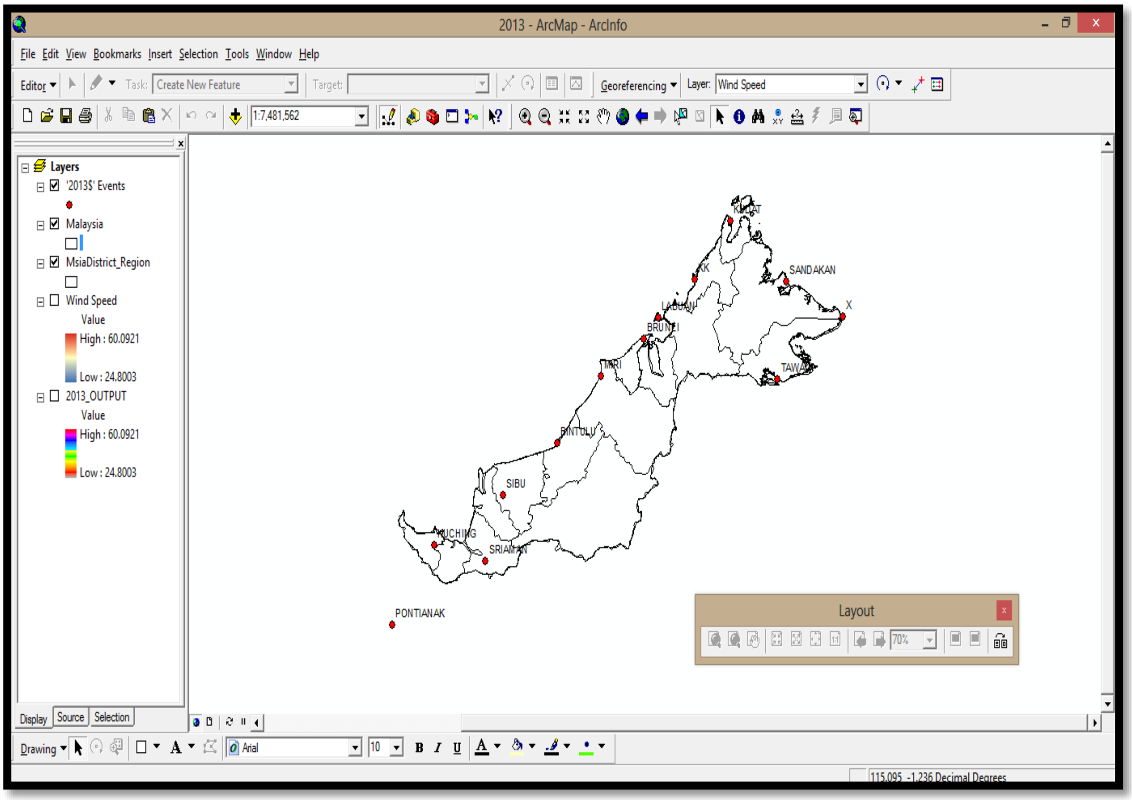


Figure 3.7: Location of 10 weather stations in Sabah and Sarawak

Step 2

Insert all of the data into GIS software. Data includes name of locations, longitude and latitude of location, and the wind speed monthly.

Attributes of Export_Output

FID	Shape *	Location	Latitude_°	Longitude_	AVG
0	Point	BRUNEI	4.94	114.93	60.1
1	Point	PONTIANAK	0.15	109.4	56.2
2	Point	SIBU	2.33	111.83	32.3
3	Point	KUCHING	1.48	110.33	32.1
4	Point	LABUAN	5.3	115.25	31.1
5	Point	SANDAKAN	5.9	118.06	30.5
6	Point	SRIAMAN	1.22	111.45	30.5
7	Point	KK	5.94	116.05	30.5
8	Point	BINTULU	3.2	113.03	29.3
9	Point	KUDAT	6.92	116.84	25.3
10	Point	MIRI	4.32	113.99	25.3
11	Point	TAWAU	4.27	117.88	24.8
12	Point	X	5.32	119.32	25

Record: 13 Show: All Selected Records (0 out of 13 Selected) Options

Figure 3.8: Data Attribute Table in GIS Software

Step 3

Produce an IDW map zoning area by using spatial analyst tools in GIS software. Inverse distance weighted (IDW) is an analysis tool use to interpolate cell values by using a linearly weighted combination of a set of sample points. As shown in Figure 3.9 below, the wind speed zoning map for Sabah and Sarawak.

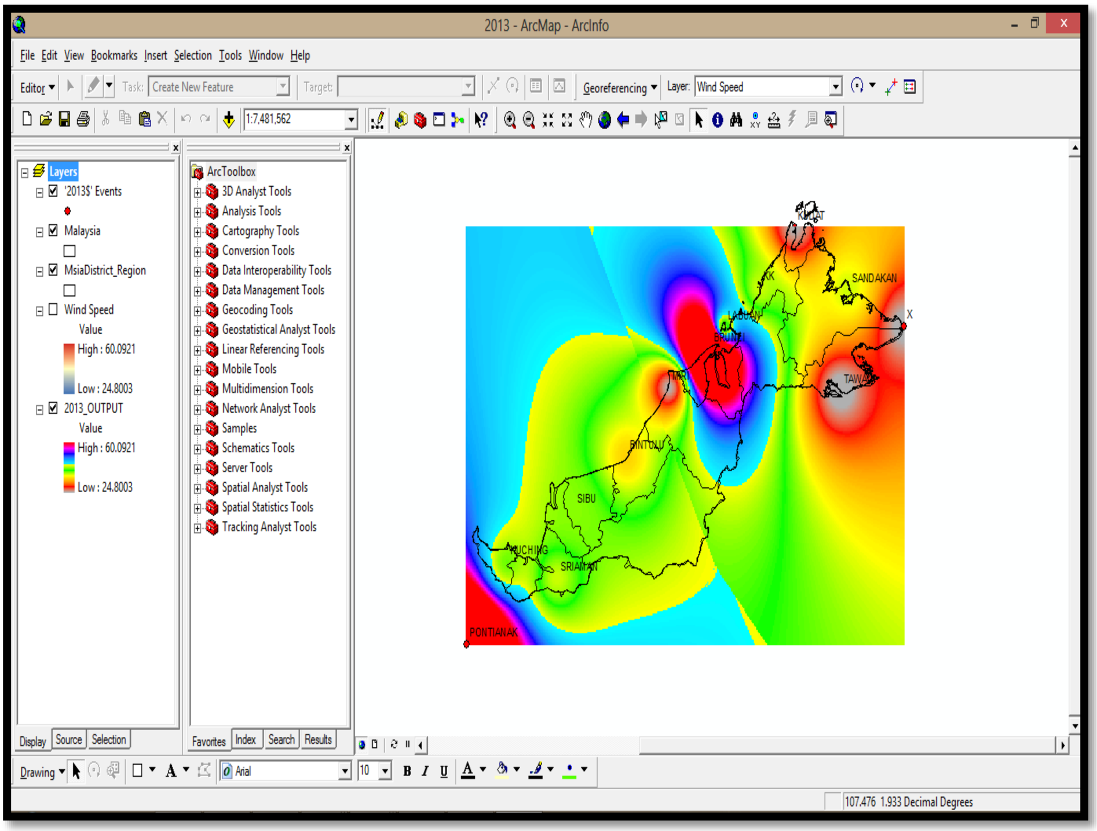


Figure 3.9: 2013 yearly average wind speeds

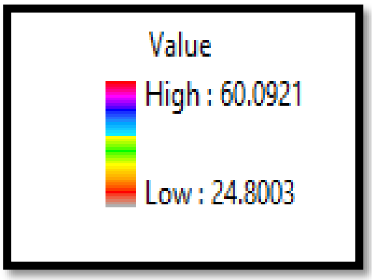


Figure 3.10: Legend for wind speed value

3.4.2 Spatial Analysis

To produce a zoning map in Sabah and Sarawak, spatial analysis tools were used. Spatial are created along Sabah and Sarawak in order to determine the average of wind speed throughout the area where weather station are not stationed. Then produce a map zoning area by extracting the wind speed map based on the feature mask data of the Malaysia District Region using spatial analyst tools as well.

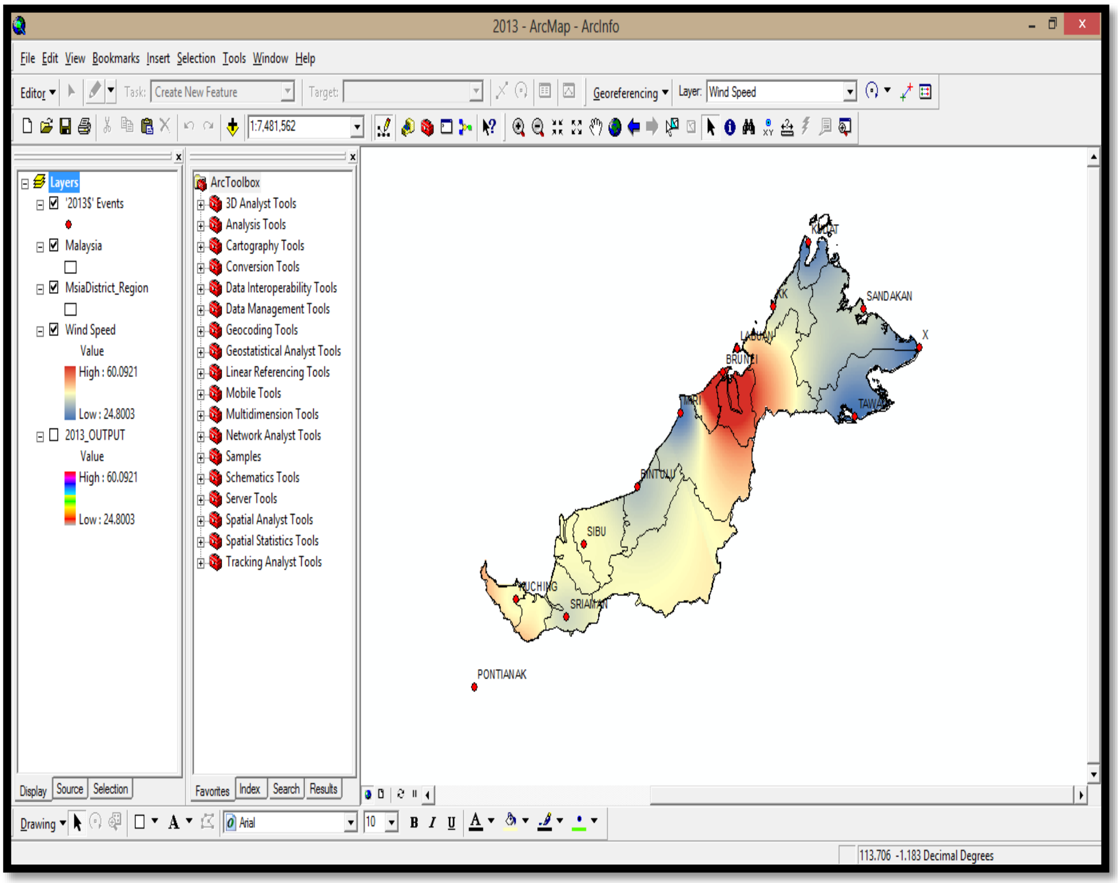


Figure 3.11: 2013 Wind speed map extracted based on Malaysia District Region

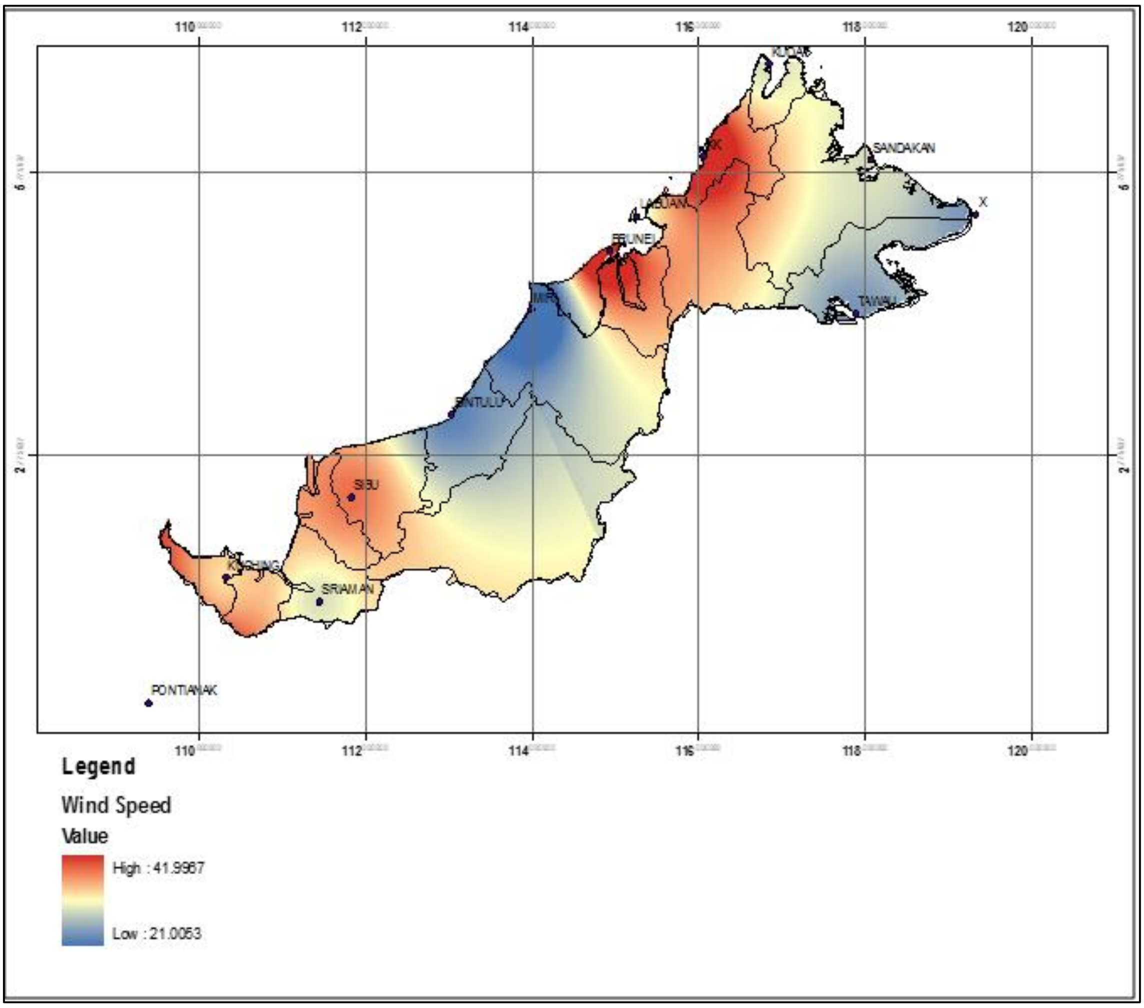


Figure 3.12: Layout view 2013 exported Map from GIS

3.5 OUTPUT

By using Geographical Information System (GIS) software, the wind speed zoning maps for early 2013 and 2014 are produced which gave a more detailed information and visualization in order to determine the risk assessment and the wind hazard cases.

3.6 SUMMARY

The overall idea of this research project has been mapped based on the simplified flow chart shown in Figure 3.1. The main software used for this research is Geographical Information System (GIS). Wind speed data sources which can be relied in the internet such as www.wunderground.com, national news website, Google Earth and Google Maps are used as data information for this research. In slightly explanation of the preparation of collecting data, pre-processing data, processing data and proceedings until the final result is obtain. The activities involved in this research must be recorded; hence, the result will be analyzed into a graph for discussion and conclusion by using Microsoft Excel.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss about the information from chapter three that was analyzed and the result of research will be presented. This chapter shows the result and the establishment made. Objectives of the study were carried out successfully. The objectives are:

1. To develop the wind hazard map in Sabah and Sarawak by using Geographical Information System (GIS) software.
2. To investigate the wind induced damage by geographical location.

4.2 WIND HAZARD MAP

All the locations of wind hazards are established by using GIS Software. Hence, by identifying the latitude and longitude of each location and is shown in Table 4.1.

Table 4.1: Longitude and Latitude of 10 Locations

Location	**Latitude (°N)**	**Longitude (°E)**
Kuching	4.94	110.33
Sri Aman	1.22	111.45
Sibu	2.33	111.83
Bintulu	3.20	113.03
Miri	4.32	113.99
Labuan	5.30	115.25
Kota Kinabalu	5.94	116.05
Kudat	6.92	116.84
Sandakan	5.90	118.06
Tawau	4.27	117.88

The Figure 4.1 and Figure 4.2 are produced from using IDW method from GIS software. The map shows the yearly average of wind speed in Sabah and Sarawak for 2013 and 2014. From the wind speed map produced, it shows those wind speed tendencies are periodically repeated anually for both state in year of 2013 and 2014. The monsoon wind devided into two seasonal which called southwest monsoon between May to September and northeast between November to Mac. Frequent strong wind was observed during the southwest monsoon in Sabah and Sarawak. This result shows opposite characteristic compare to the Peninsular Malaysia where the higher wind speed recorded during the Northeast Monsoon.

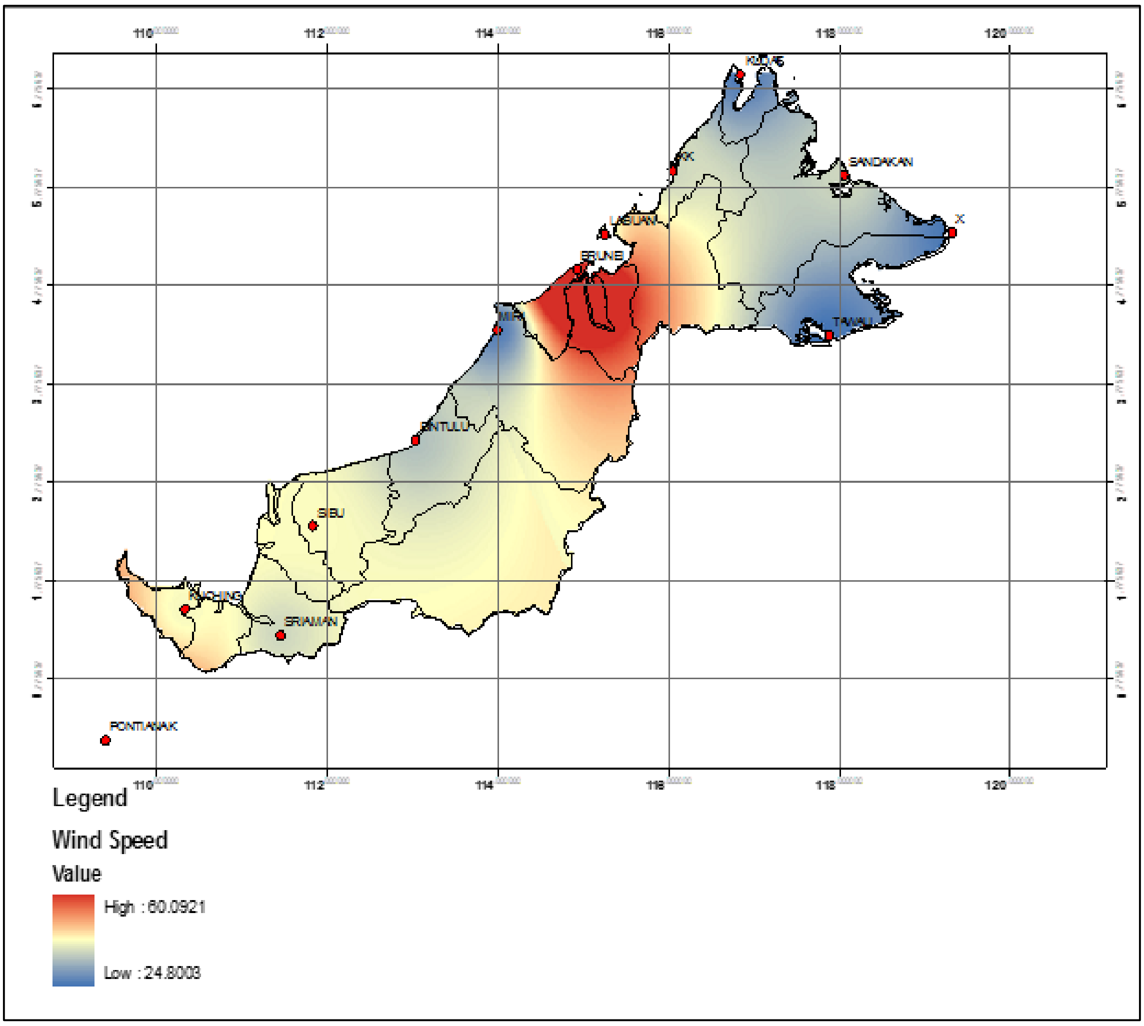


Figure 4.1: 2013 Yearly Average Wind Speed Map

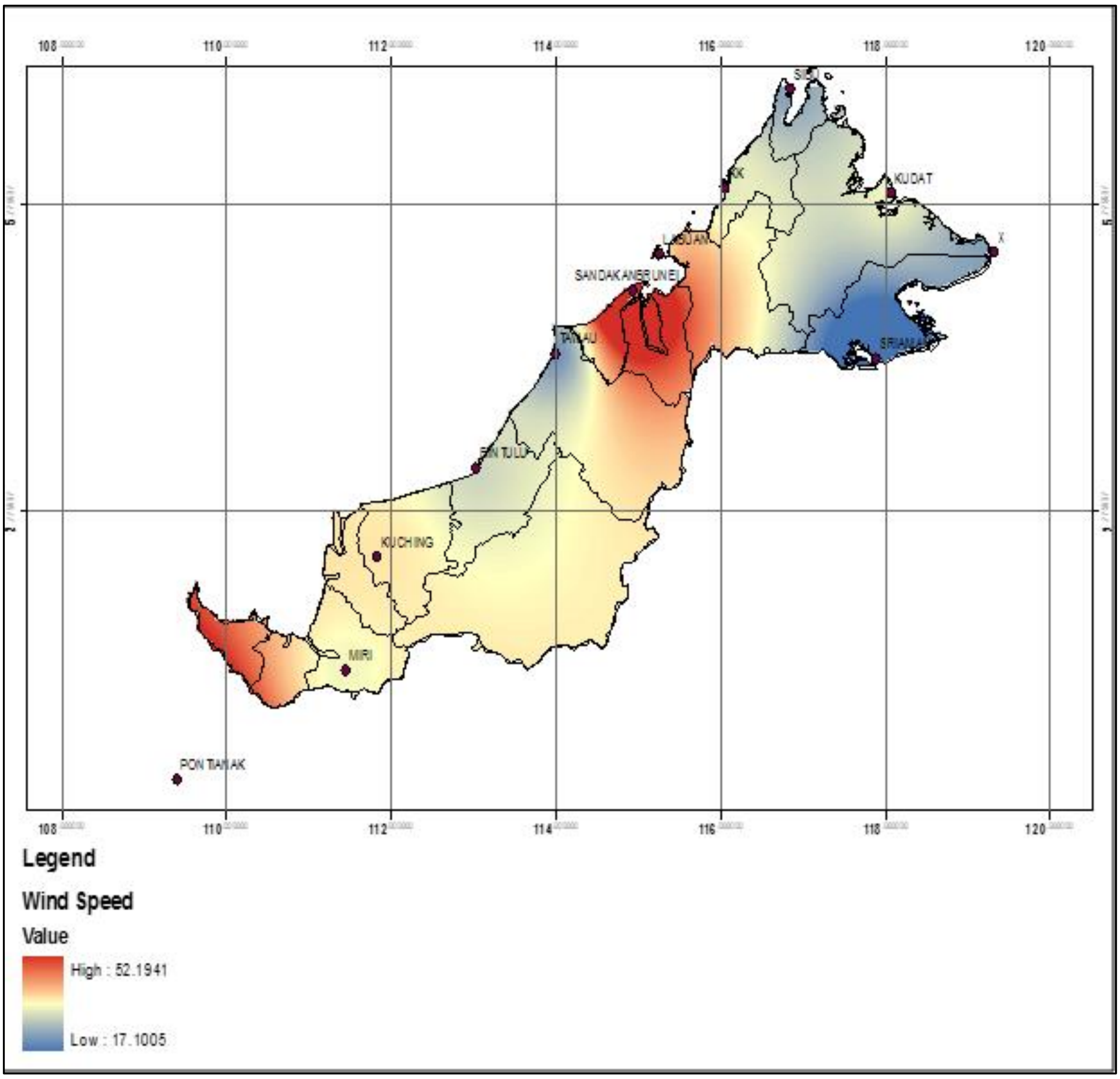


Figure 4.2: 2014 Yearly Average Wind Speed Map

4.3 DEVELOP THE RELATIONSHIP BETWEEN WIND SPEED, DAMAGE AND MONSOON SEASON

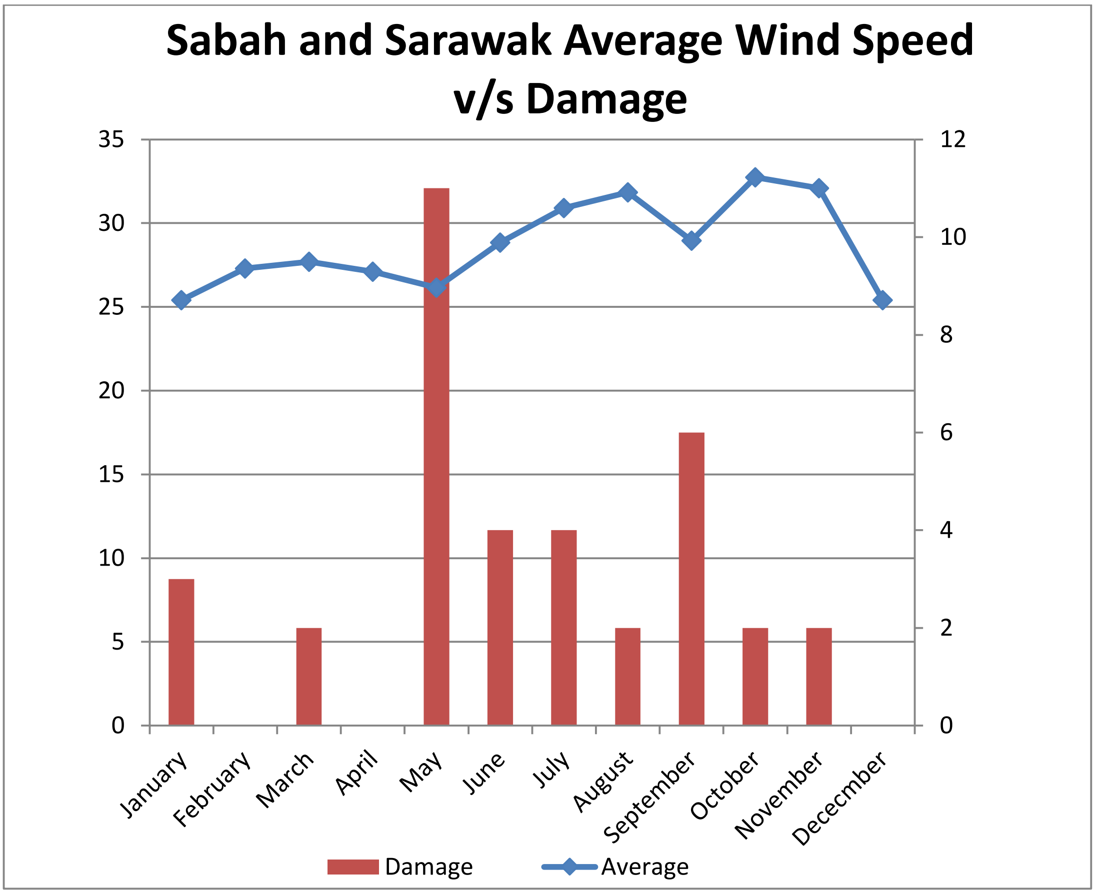


Figure 4.3: Sabah and Sarawak Average Wind Speed v/s Damage

Based on wind speed data and damage collected from year 2013 to 2014, Sarawak and Sarawak average wind speed v/s damage graph was established. The establishments of the graph are to develop the relationship between wind speed, damage and monsoon season. As we know that the monsoon season in Sabah and Sarawak is southwest season which the month of May to September. Total damaged reported for year 2013 to 2014 in Sabah and Sarawak is 27 cases in southwest monsoon season. From the figure above, overall in 2013 and 2014 data, the highest total damage happened in May with 11 wind hazards cases and following by September with 6 cases, June and May with 4 cases both and August with 2 cases. The wind speed shows an average high wind speed during monsoon season. From this graph, it has been proven that total damage for both years in Sabah and Sarawak are significantly to the southwest monsoon season.

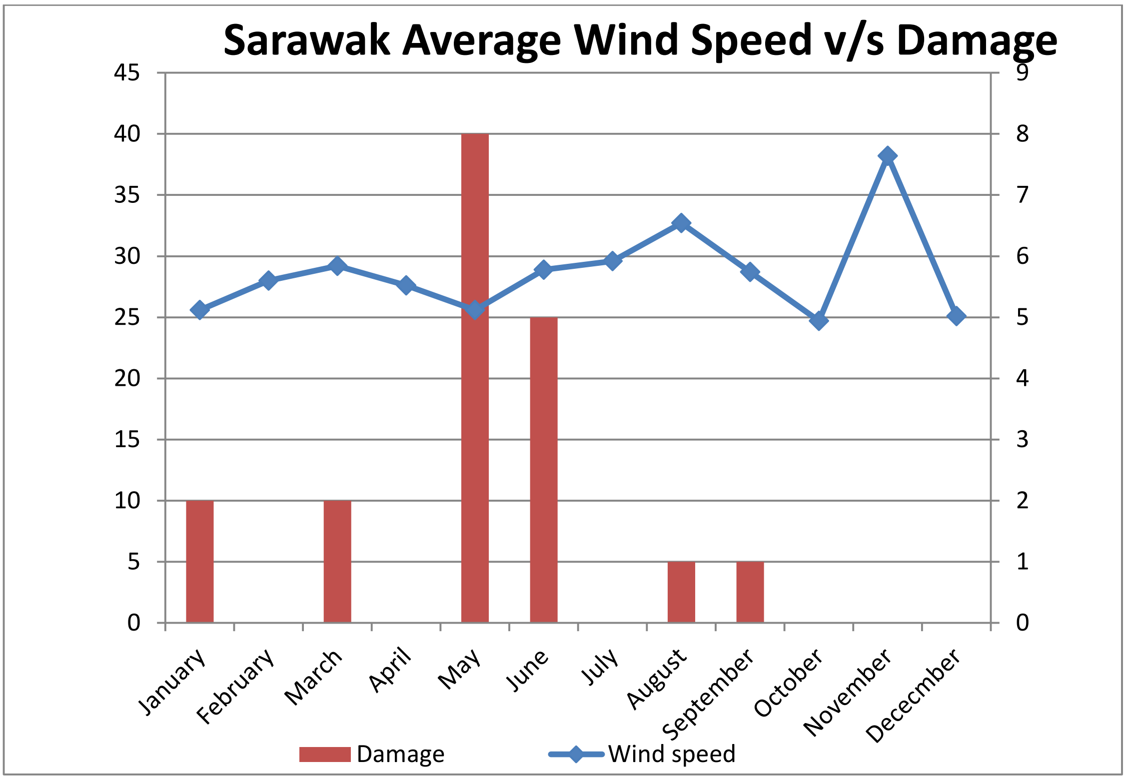


Figure 4.4: Sarawak Average Wind Speed v/s Damage

Based on wind speed data and damage collected from year 2013 to 2014, Sarawak average wind speed v/s damage graph was established. The establishment of the graph is to develop the relationship between wind speed, damage and monsoon season. As we know that the monsoon season in Sabah and Sarawak is southwest season which the month of May to September. From the figure above, the highest total damage happened in May and following by June, August and September. The wind speed shows an average wind speed during monsoon season. But, no damage reported in July. From the investigation of wind induced damage by geographical location, Sarawak is lowly significant to southwest monsoon. This is because the graphical location different in Sarawak. Sarawak is more localized thunderstorm frequently occurred compared to Sabah. Hence, high damage reported during inter-monsoon season.

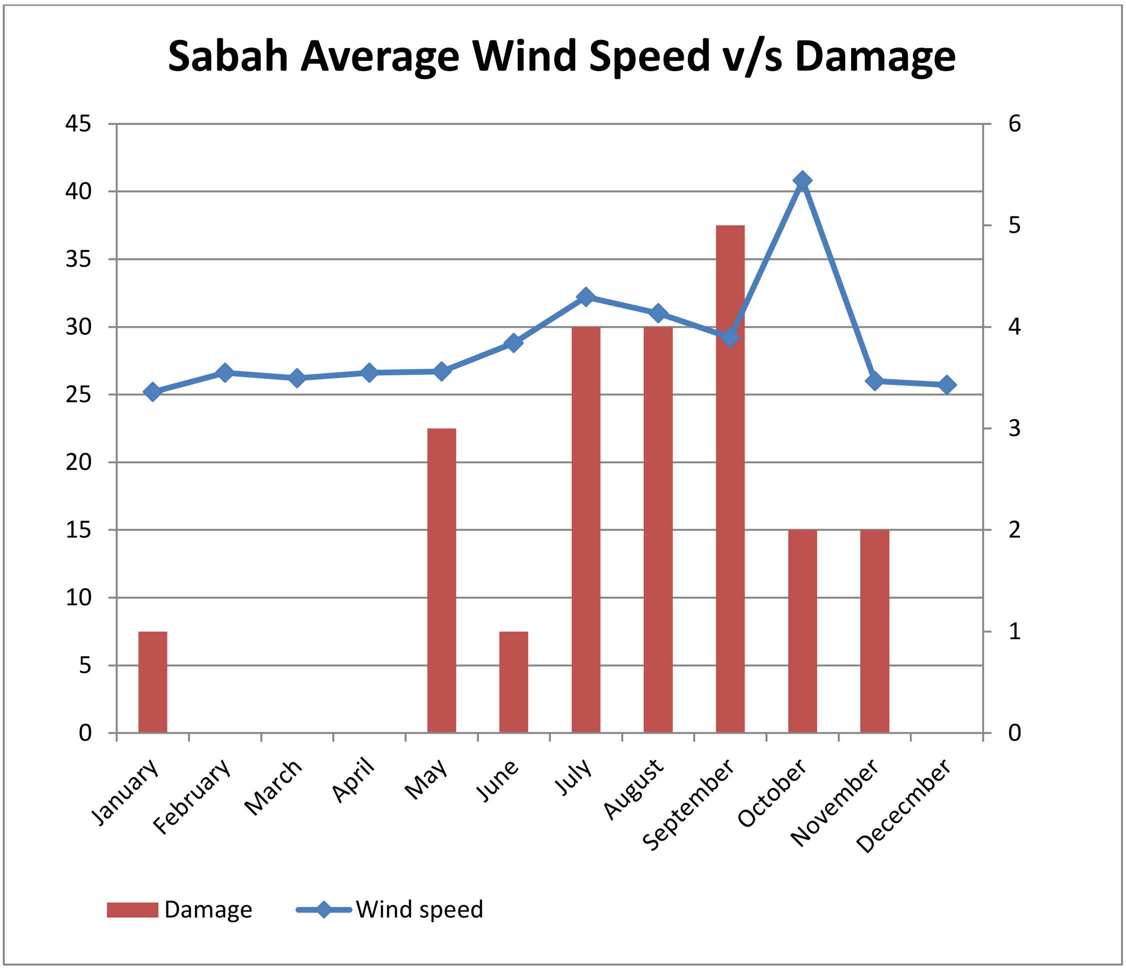


Figure 4.5: Sabah Average Wind Speed v/s Damage

Based on wind speed data and damage collected from year 2013 to 2014, Sabah average wind speed v/s damage graph was established. The establishment of the graph is to develop the relationship between wind speed, damage and monsoon season. As we know that the monsoon season in Sabah and Sarawak is southwest season which the month of May to September. From the figure above, the highest total damage happened in September and following by July, August and May. The wind speed shows an average high wind speed during the monsoon season. From the investigation of wind induced damage by geographical location, Sabah is higher significant to southwest monsoon. This is because the graphical location different in Sabah. Sabah more dominated to southwest monsoon season. Hence, high damage reported and high wind speed during this season in Sabah.

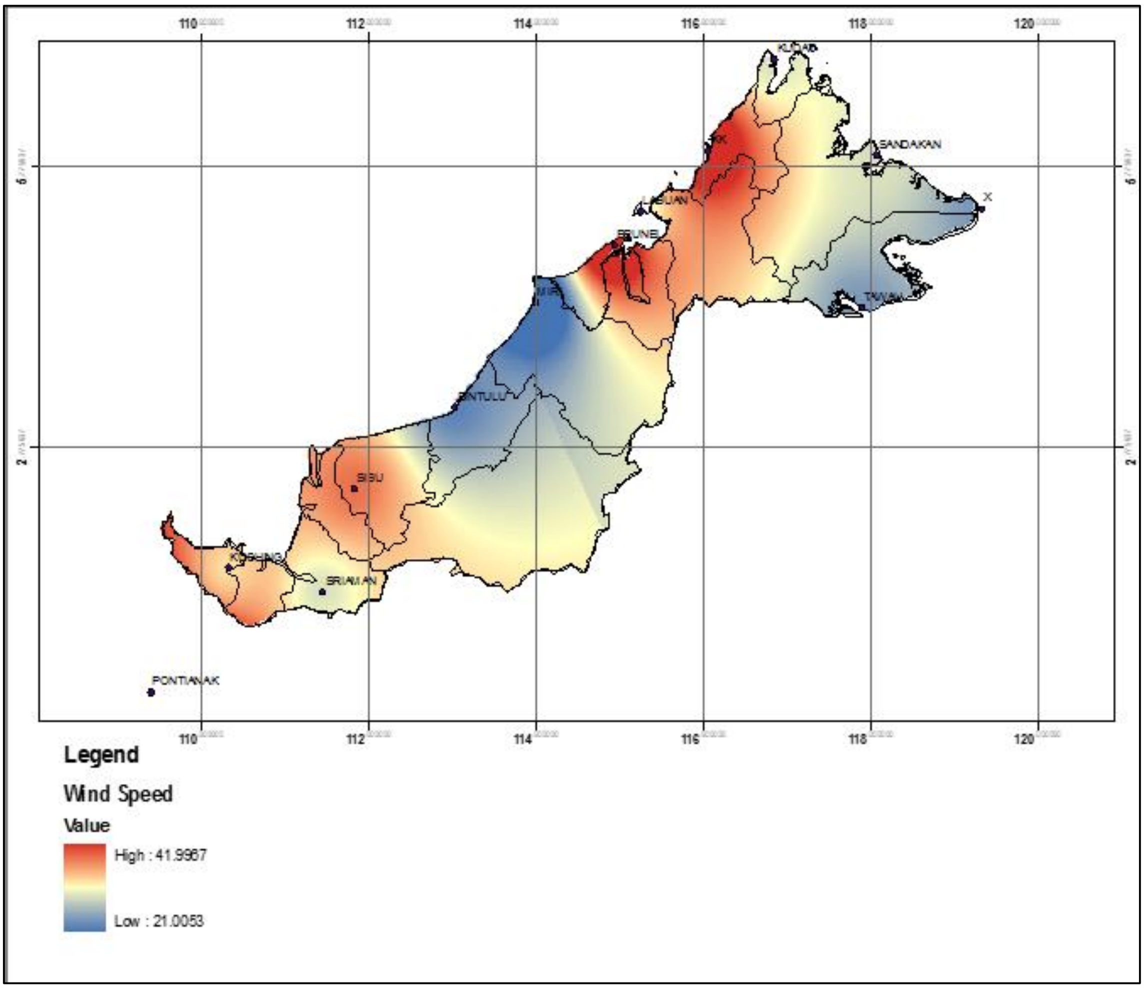


Figure 4.6: Wind Hazard Case I

Based on Figure 4.6, the wind hazard case I was found in Kuching, Sarawak on October in year 2013. The wind hazard case was reported on some damage to the certain area of the city such as 4 coffee shops and some houses. Strong winds storm havoc across Kuching during that month, with 4 coffee shops in Pending having its tables, chairs and glassware literally blown away by the shear force of the wind. Several shops and houses in a number of areas in the city also had their roofs blown off during the storm, although no major incident was reported. From the wind speed data collected during the month of October 2013 and mapping it using GIS software, it shows Kuching was in a high value of wind speed area in the figure above.

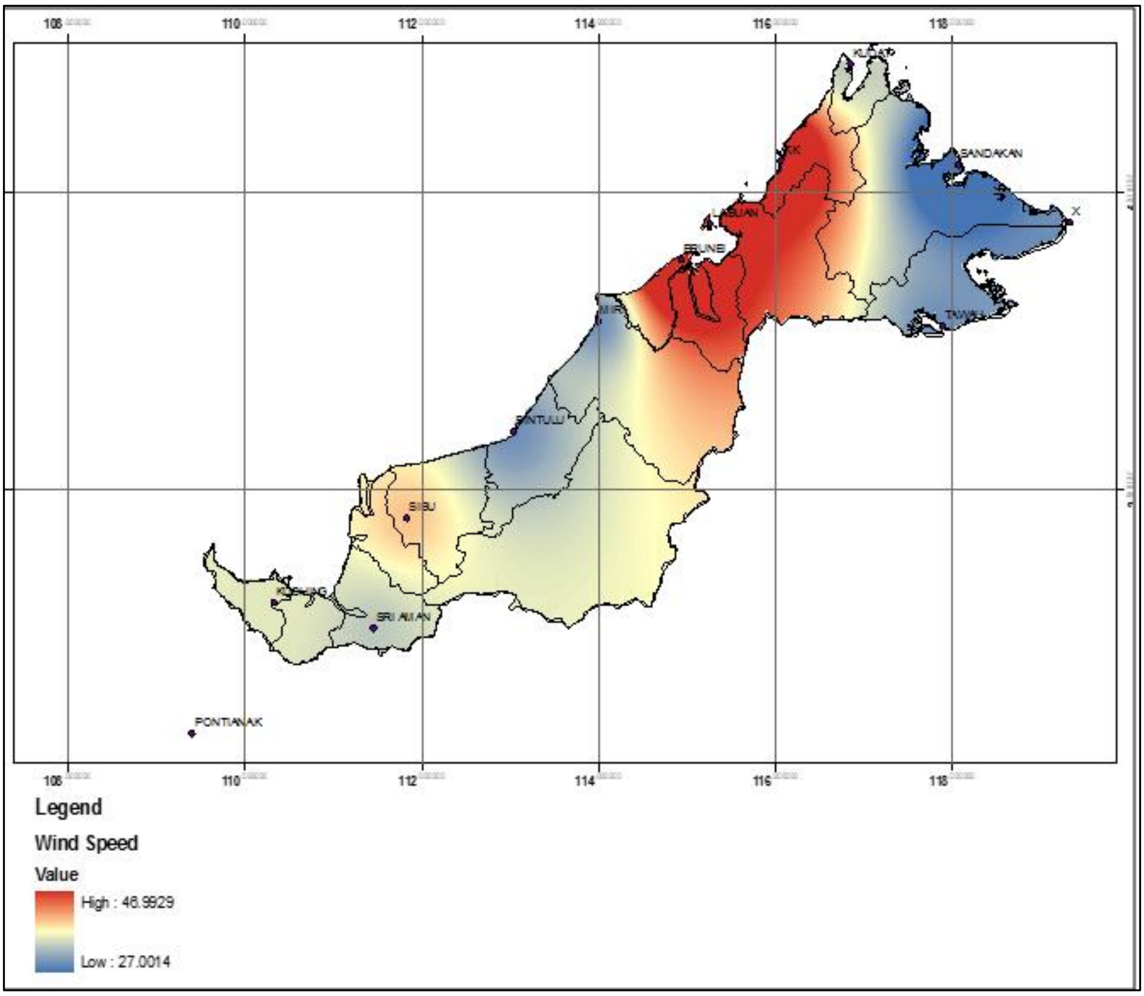


Figure 4.7: Wind Hazard Case II

Based on Figure 4.7, the wind hazard case II was found in Kota Kinabalu, Sabah on July in year 2013. The wind hazard case was reported on some damage to the certain area of the city such as houses, vehicles and other public properties. Strong winds storm havoc across Kota Kinabalu during that month .For case in Kota Kinabalu with some houses of roof blown away and damage on 2 vehicles because of uprooted trees. Several shops and houses in a number of areas in the city also had their roofs blown off during the storm, although no major incident was reported and as well as canopies and awnings being blown away. From the wind speed data collected during the month of July 2013 and mapping it using GIS software, it shows Kota Kinabalu was in a high value of wind speed area in the figure above.

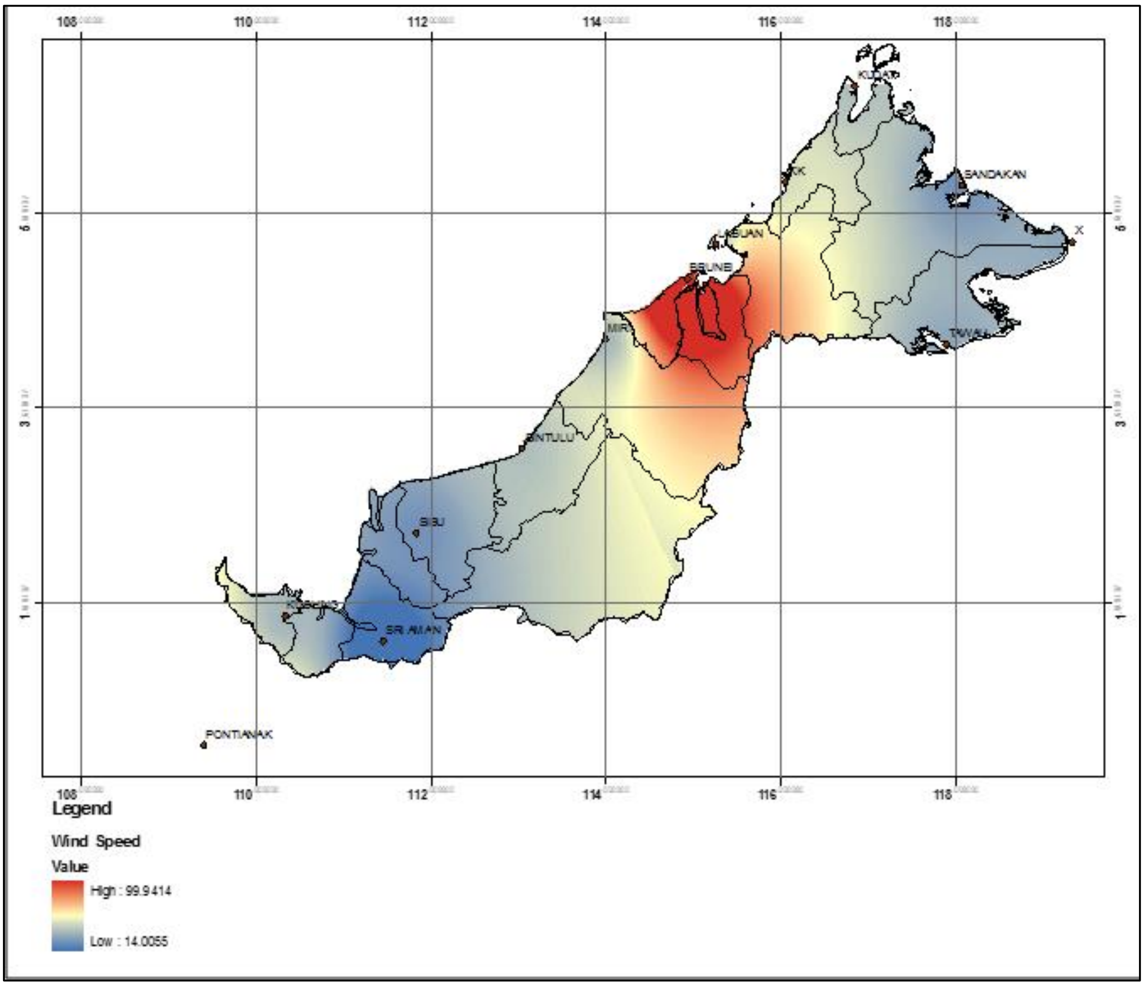


Figure 4.8: Wind Hazard Case III

Based on Figure 4.8, the wind hazard cases III was found in Bintulu, Sarawak on September in year 2013. The wind hazard case was reported on some damage to the certain area of the city such as houses and vehicles. Strong winds storm havoc across Bintulu during that month .For case in Bintulu with 10 houses of roof blown away by the shear force of the wind and damage on 4 vehicles because of uprooted trees although no major incident was reported and as well as canopies and awnings being blown away. From the wind speed data collected during the month of September2013 and mapping it using GIS software, it shows Bintulu was in a average high value of wind speed area in the figure above.

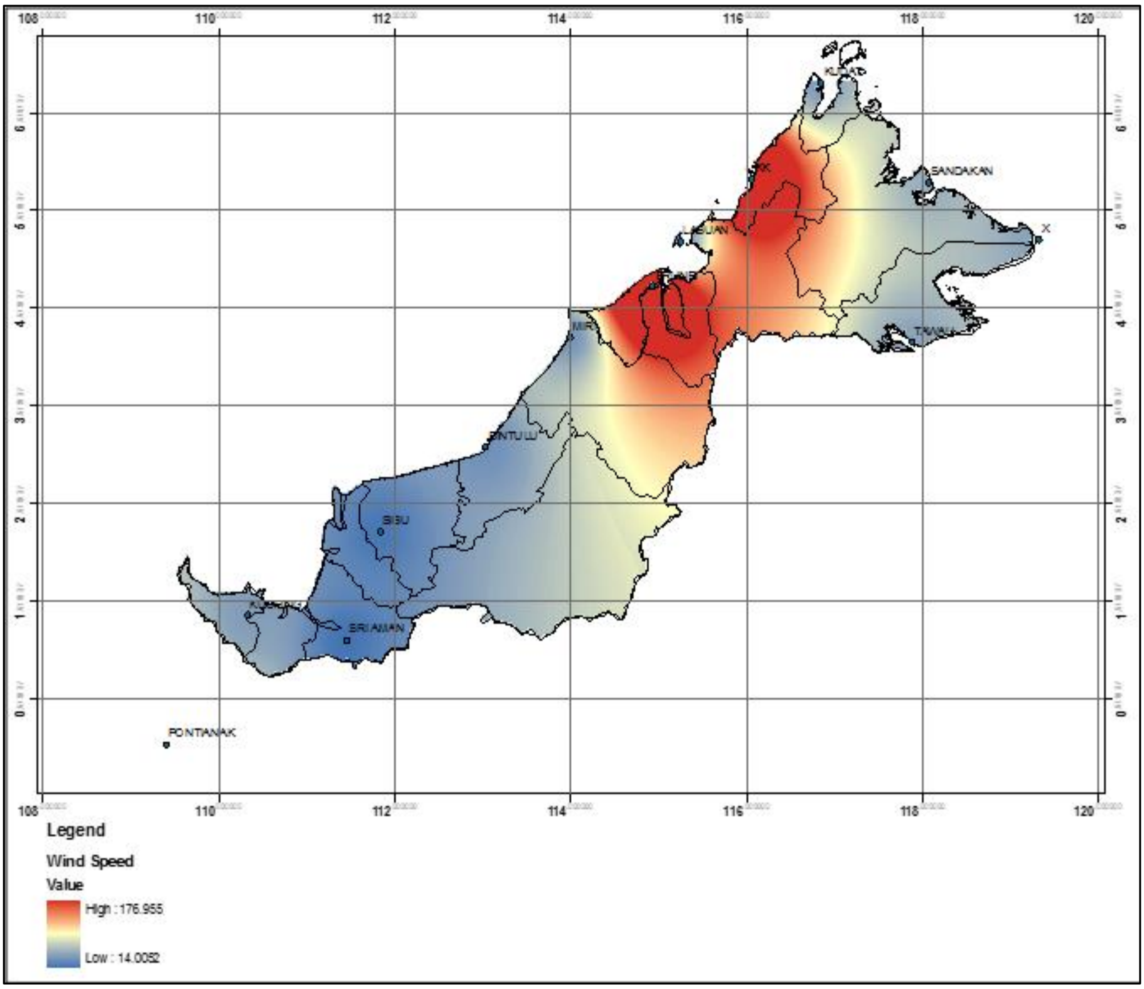


Figure 4.9: Wind Hazard Cases IV

Based on Figure 4.9, the wind hazard case IV was found in Miri, Sarawak on October in year 2014. The wind hazard case was reported on some damage to the certain area of the city such as houses, vehicles, mosque, school and other public properties. Strong winds storm havoc across Miri that month .For case in Miri with some houses of roof blown away by the shear force of the wind, 1 mosque structure building collapsed and 1 school roof blown away during the storm. There are also damage on some vehicles because of uprooted trees and some other public properties such as bus stop although no major incident was reported and as well as canopies and awnings being blown away. From the wind speed data collected during the month of Miri 2014 and mapping it using GIS software, it shows Miri was in a high value of wind speed area in the figure above.

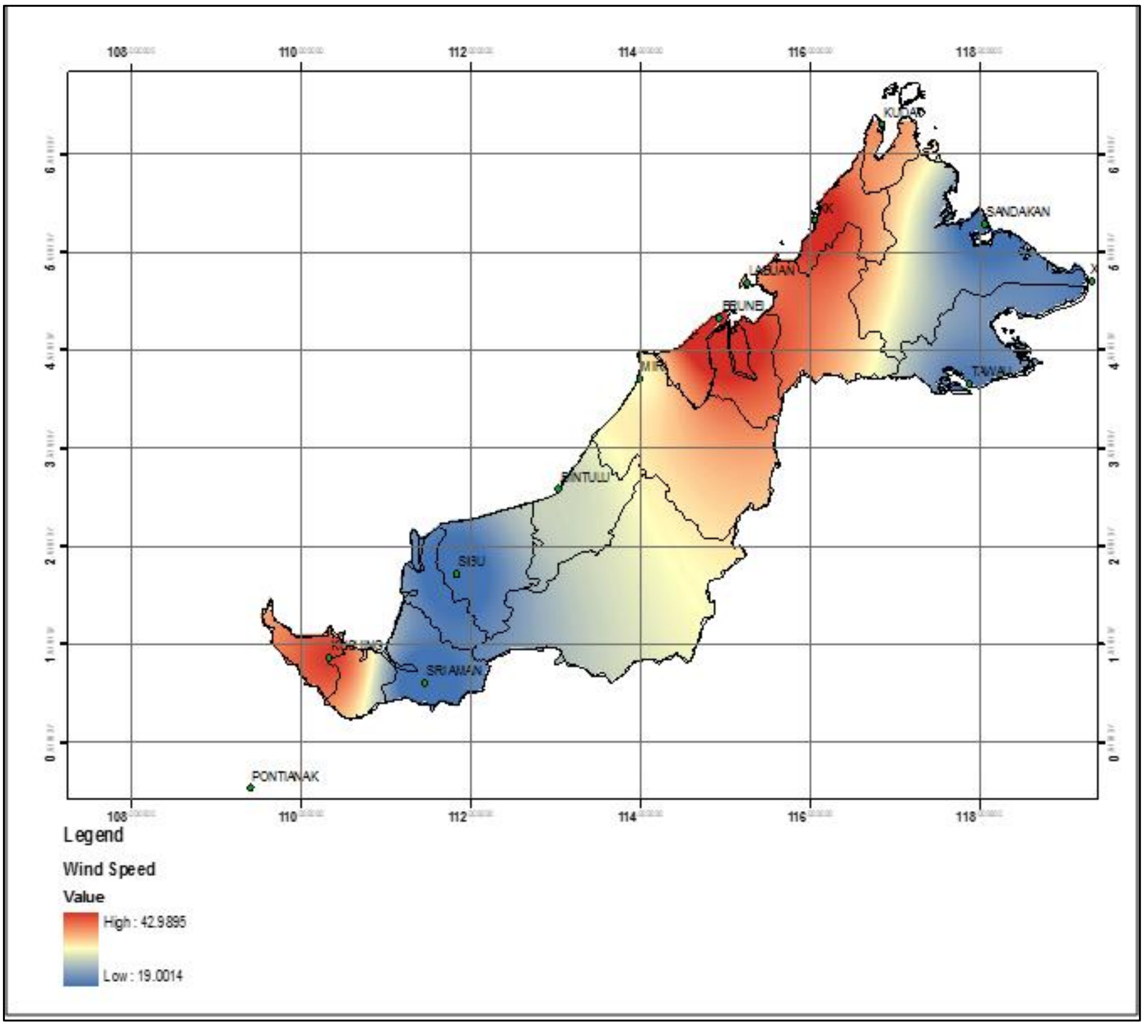


Figure 4.10: Wind Hazard Cases V

Based on Figure 4.10, the wind hazard case IV was found in Keningau, Sabah on September in year 2014. The wind hazard case was reported on some damage to the certain area of the city such as houses. Strong winds storm havoc across Keningau that month .For case in Keningau with 49 houses of roof blown away by the shear force of the wind during the storm. There are also damage on some vehicles because of uprooted trees and some other public properties such as bus stop although no major incident was reported and as well as canopies and awnings being blown away. From the wind speed data collected during the month of Keningau 2014 and mapping it using GIS software, it shows Keningau was in a high value of wind speed area in the figure above.

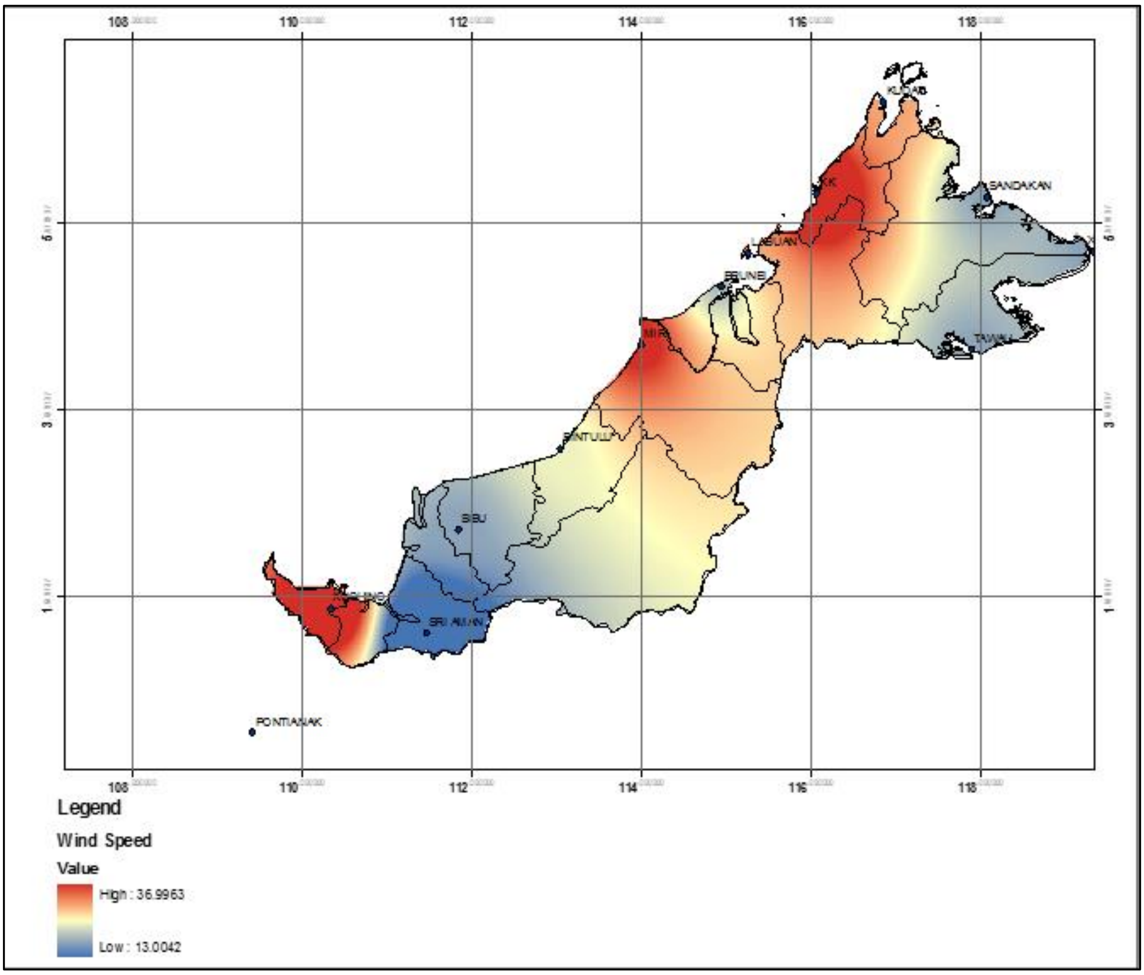


Figure 4.11: Wind Hazard Cases VI

Based on Figure 4.11, the wind hazard case VII was found in Kuching, Sarawak on June in year 2014. The wind hazard case was reported on some damage to the certain area of the city such as houses, vehicles and death. Strong winds storm havoc across Kuching that month .For case in Kuching with 20 houses of roof blown away by the shear force of the wind during the storm. There are also damage on vehicle because of uprooted trees and some other public properties such as bus stop although no major incident was reported and as well as canopies and awnings being blown away. 1 death reported, a police corporal attached to General Operations Force (GOF) was killed after he was hit by a falling tree during brief storm. From the wind speed data collected during the month of Kuching2014 and mapping it using GIS software, it shows Kuching was in a high value of wind speed area in the figure above.

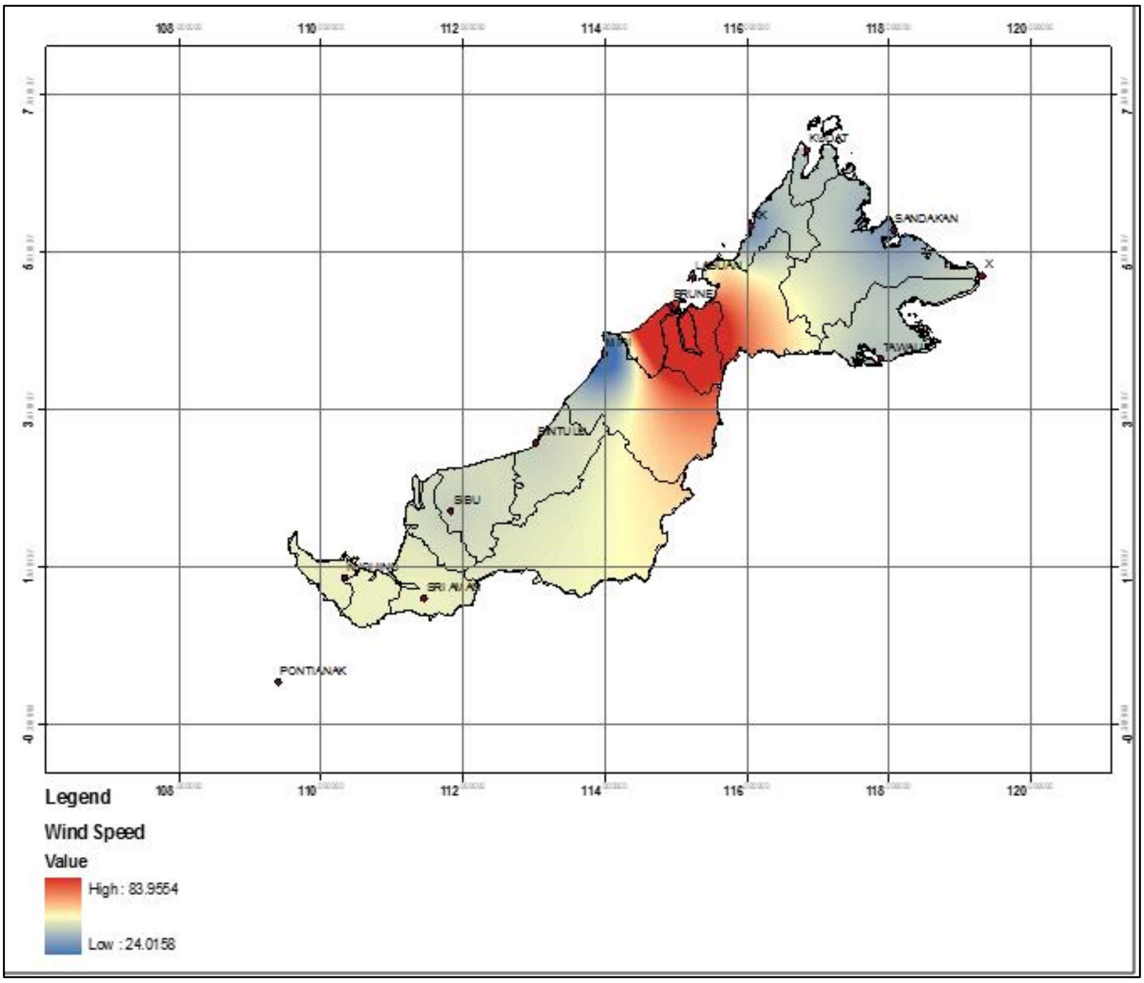


Figure 4.12: Wind Hazard Cases VII

Based on Figure 4.12, the wind hazard case VII was found in Sibu, Sarawak on July in year 2013. The wind hazard case was reported on some damage to the certain area of the city such as houses and public properties. Strong winds storm havoc across Sibu that month .For case in Sibu with 20 houses of roof blown away by the shear force of the wind during the storm and some other public properties such as bus stop although no major incident was reported and as well as canopies and awnings being blown away. From the wind speed data collected during the month of Kuching2014 and mapping it using GIS software, it shows Kuching was in a high value of wind speed area in the figure above.

4.4 SUMMARY

Wind hazard cases happens is because of the higher wind speed during the monsoon season which is the cause of wind induced damage for both state Sabah and Sarawak. As to assess the risk of the wind events in Sabah and Sarawak and to mitigate the increases of wind related hazard cases, wind hazard map for both Sabah and Sarawak are produced in order to analyze the wind phenomenon in Sabah and Sarawak.

Based on the results obtained, the relationship between the wind events in Sabah and Sarawak are highly corresponding to the changing of monsoon season which is periodically repeated annually.

In Sabah, a significant amount of wind related hazard cases are reported to happened during the southwest monsoon which is between May to September when comparing to other seasons.

For Sarawak region, a lower amount of wind hazard cases can be observed to be reported during the monsoon seasons, but a significant amount of wind hazard cases are reported during the inter-change of monsoon seasons which is during the month of April and October.

So in conclusion, it can be observed that Sabah is a state that are highly responsive to wind events during the period of Southwest monsoon season while for Sarawak, during the inter-changing of monsoon season is when Sarawak has the strongest wind events.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 INTRODUCTION

This chapter will discuss about the conclusion for each of the objectives outline for this study. For future study, several recommendations also included at the end of the chapter to improve the study for this research. The conclusion for this study is to achieve the objectives that have stated earlier in the thesis.

5.2 CONCLUSION

Nowadays, there are increasing number of wind hazard damage in Sabah and Sarawak. Wind induced damage has become expressively reported widely in Malaysia. Numeral of study was conducted to mitigate and reduce wind risk in Malaysia. However, most of the studies were conducted focusing to Peninsular Malaysia. There are very minimum information related to the wind characteristic in Sabah and Sarawak.

As a conclusion, this result shows opposite characteristic compare to the Peninsular Malaysia where the higher wind speed recorded during the Northeast Monsoon. This study also identify that damage occured in Sabah are significantly related to the monsoon season where numbers of damage is highly reported during this period. However in Sarawak there are lower significant relationship between the damage occured and the monsoon season. The damage were reported highly during the inter change of the monsoon season. During the inter change monsoon localised thunderstorm were frequently occured. Therefore the wind induce damage in Sarawak are significantly due to the micro scale event rather than seasonal monsoon wind. From all the result obtain, it can be conclude that wind characteristic is differs from place to place. Consequently, the wind risk is influenced by the geographical position at the specific location. Furthermore all consideration due to wind mitigation used in Peninsular Malaysia cannot simply consider in Sabah and Sarawak.

There are two objectives in this study. To obtain the result, the objectives have been verified and will be discussed from previous chapter for each objective.

5.2.1 Objective 1: To Develop The Wind Hazard Map in Sabah and Sarawak by Using Geographical Information System (GIS) Software.

The first objective is to develop the wind hazard map in Sabah and Sarawak by using GIS software. The objective has been achieved by collecting data of total 10 stations by determining the longitude and latitude starting from January 2013 until December 2014. From these data, a map has been produced by using GIS software and interpolation using IDW method. GIS is software that to do simulation based on its capability of storing, editing, combining, manipulating, editing and interpreting the data. Therefore, wind hazard map were able to produce as a given guideline in Sabah and Sarawak for future prevention.

5.2.2 Objective 2: To Investigate The Wind Induced Damage by Geographical Location

The second objective is to investigate the wind induced damage by geographical location. The objective has been achieved by collecting data of wind hazard cases in Sabah and Sarawak. The chart shows that the relationships between wind speeds, wind induce damage and monsoon season. Wind characteristic is differs from place to place and wind risk is influenced by the geographical position at the specific location. Furthermore all consideration due to wind mitigation used in Peninsular Malaysia cannot simply consider in Sabah and Sarawak.

5.3 RECOMENDATION

This study is about the evaluation of wind hazard over Sabah and Sarawak has given an appropriate result. For future studies, there are a few recommendations to obtain more accurate results.

The first recommendation is to collect more data of wind speed to be input in GIS software. In this study, monthly average wind speed data and two years periods only were used. In other to improve the future work research studies, so, it is recommended to collect more data of longer study period and use daily wind speed data.

Second recommendation is to have more data connecting and multiple sources to be input in the chart in Microsoft Excel to determine the relationship between wind speed, wind hazard cases and monsoon season. In this study, wind hazard cases are collected from website news and articles. In order to improve the future work research studies, it is recommended to have more data connecting and multiple sources.

The final recommendation is to investigate more factors affecting the wind hazard in Sabah and Sarawak to get more accurate result. In this study, only considered the geographical location of Sabah and Sarawak affects the wind induced damage. In order to improve the future work research studies, it is recommended to consider on investigate more factors such as related effect of wind speed due to topographic and roughness.

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APPENDICES

APPENDIX A

	Temperature, C			Dew Point, C			Humidity			Sea Level Pressure, hPa			Wind Speed, km/h			
Bintulu	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Events**	**WindDirDegrees**
1/1/2013	30	28	25	27	26	24	100	87	70	1011	1009	1007	19	11	Rain	28
1/2/2013	31	27	24	26	25	24	100	84	63	1011	1009	1007	16	6		338
1/3/2013	30	27	24	26	25	24	100	85	65	1011	1010	1008	23	10	Rain	22
1/4/2013	29	27	24	26	24	24	100	91	74	1010	1007	1005	21	8	Rain	228
1/5/2013	31	28	24	26	24	23	100	88	66	1010	1007	1004	24	10	Rain	198
1/6/2013	31	28	24	26	24	22	100	83	54	1010	1008	1006	16	8	Rain	192
1/7/2013	32	28	24	26	24	22	94	80	58	1011	1009	1007	14	6	Thunderstorm	46
1/8/2013	31	28	24	26	24	23	96	85	54	1011	1009	1007	24	6	Rain	131
1/9/2013	31	28	24	26	24	23	100	84	60	1010	1008	1005	16	6	Rain	42
1/10/2013	31	27	23	25	24	23	100	84	63	1010	1007	1005	21	10	Rain-Thunderstorm	215
1/11/2013	29	27	24	25	24	23	100	85	58	1010	1009	1007	14	8	Rain	279
1/12/2013	30	27	24	25	24	23	100	88	64	1011	1010	1008	80	8	Rain	204
1/13/2013	30	27	23	25	24	22	100	85	65	1012	1010	1008	14	8	Rain-Thunderstorm	226
1/14/2013	30	27	23	25	24	23	100	90	69	1012	1011	1009	14	6	Rain	178
1/15/2013	29	27	25	25	24	23	100	88	70	1013	1011	1010	16	8	Rain	41
1/16/2013	30	28	25	25	24	23	100	84	61	1013	1012	1010	14	6	Rain	356
1/17/2013	29	27	24	26	24	24	100	89	71	1013	1011	1009	21	8	Rain-Thunderstorm	18

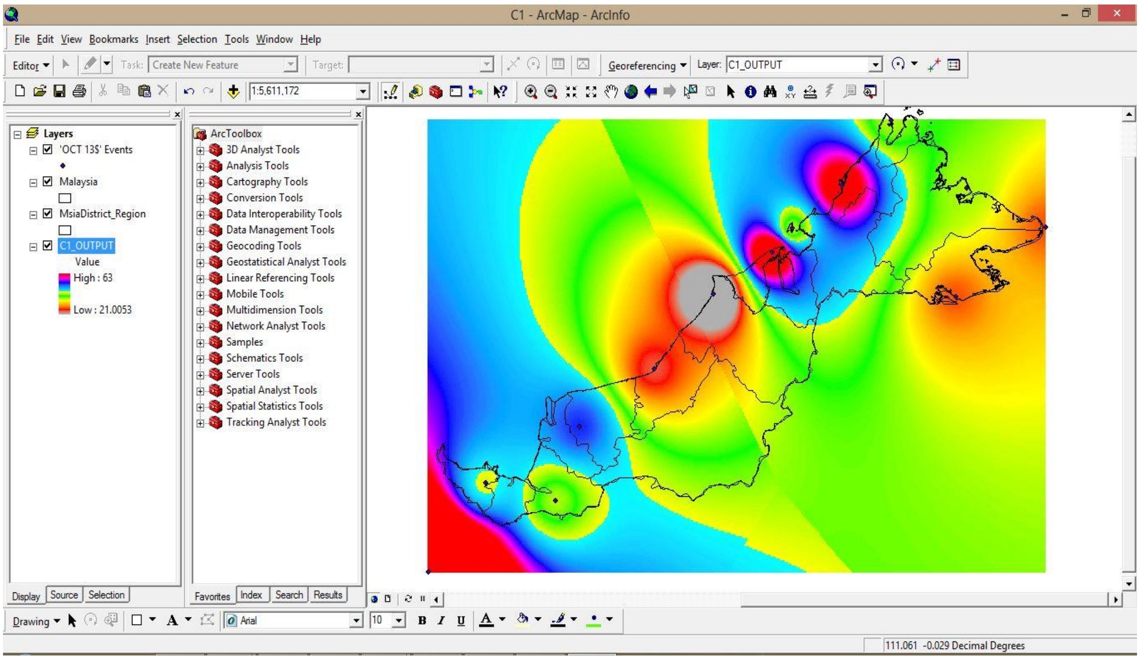
	Temperature, C			Dew Point, C			Humidity			Sea Level Pressure, hPa			Wind Speed, km/h			
Bintulu	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Events**	**WindDirDegrees**
1/18/2013	31	28	24	26	24	23	100	83	60	1012	1010	1008	29	10		31
1/19/2013	31	28	26	26	25	24	94	83	60	1012	1010	1008	27	13		26
1/20/2013	31	28	25	26	25	24	95	83	62	1013	1011	1009	24	8	Rain-Thunderstorm	33
1/21/2013	33	29	25	26	24	22	100	79	53	1013	1011	1009	26	11		34
1/22/2013	32	28	24	26	24	24	89	79	63	1013	1012	1010	21	13		9
1/23/2013	31	29	27	24	24	23	84	77	60	1013	1011	1009	32	18		5
1/24/2013	30	28	27	24	24	23	84	77	62	1013	1012	1010	26	11	Rain	355
1/25/2013	29	27	24	25	23	22	100	81	63	1013	1011	1009	16	8		8
1/26/2013	30	27	24	26	23	21	100	79	58	1013	1012	1009	16	10	Rain	21
1/27/2013	32	29	25	25	24	23	94	82	62	1014	1012	1010	16	8	Rain	31
1/28/2013	28	27	24	25	24	23	94	88	72	1014	1012	1010	16	6	Rain	10
1/29/2013	31	27	24	26	24	23	100	85	64	1013	1012	1010	21	8	Rain-Thunderstorm	11
1/30/2013	31	28	24	26	25	23	100	84	61	1014	1012	1010	27	13	Rain-Thunderstorm	28
1/31/2013	30	28	27	25	24	24	89	80	16	1014	1012	1010	23	14	Rain-Thunderstorm	16

APPENDIX B

	Temperature, C			Dew Point, C			Humidity			Sea Level Pressure, hPa			Wind Speed, km/h			
Miri	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Events	WindDirDegrees
10/1/2014	33	28	23	28	24	23	100	86	66	1012	1010	1008	16	8	Rain-Thunderstorm	146
10/2/2014	32	28	24	27	25	23	100	82	63	1011	1009	1007	19	8	Rain-Thunderstorm	171
10/3/2014	30	27	24	25	24	24	100	90	68	1011	1009	1007	14	8	Rain-Thunderstorm	131
10/4/2014	32	28	24	26	25	24	100	89	68	1010	1008	1006	21	8	Rain-Thunderstorm	163
10/5/2014	27	26	24	25	24	24	100	96	84	1012	1010	1008	29	8	Rain-Thunderstorm	163
10/6/2014	29	26	23	25	24	23	100	94	74	1012	1010	1008	29	11	Rain	176
10/7/2014	29	26	23	26	24	23	100	91	67	1013	1010	1006	35	13	Rain	184
10/8/2014	31	27	23	27	25	24	100	87	71	1011	1008	1006	21	10	Rain	186
10/9/2014	27	26	23	25	24	23	100	95	82	1012	1010	1008	34	16	Rain	197
10/10/2014	28	24	21	25	23	22	100	95	79	1011	1009	1008	21	11	Rain	140
10/11/2014	30	27	23	27	24	23	100	88	71	1012	1009	1007	32	10	Rain	188
10/12/2014	31	27	23	27	25	23	94	89	78	1012	1010	1009	10	5		133
10/13/2014	32	28	23	28	26	23	100	86	70	1013	1011	1009	10	6		53
10/14/2014	32	27	22	28	25	23	94	82	66	1012	1010	1008	11	6	Thunderstorm	59
10/15/2014	32	28	24	28	24	22	94	83	65	1012	1009	1008	14	8	Rain	104
10/16/2014	33	28	23	28	24	22	94	82	64	1012	1010	1008	11	8	Rain	124
10/17/2014	31	28	24	27	24	23	94	84	70	1011	1009	1006	11	6		70
10/18/2014	33	29	24	27	25	24	95	85	69	1010	1008	1006	14	6	Rain-Thunderstorm	90

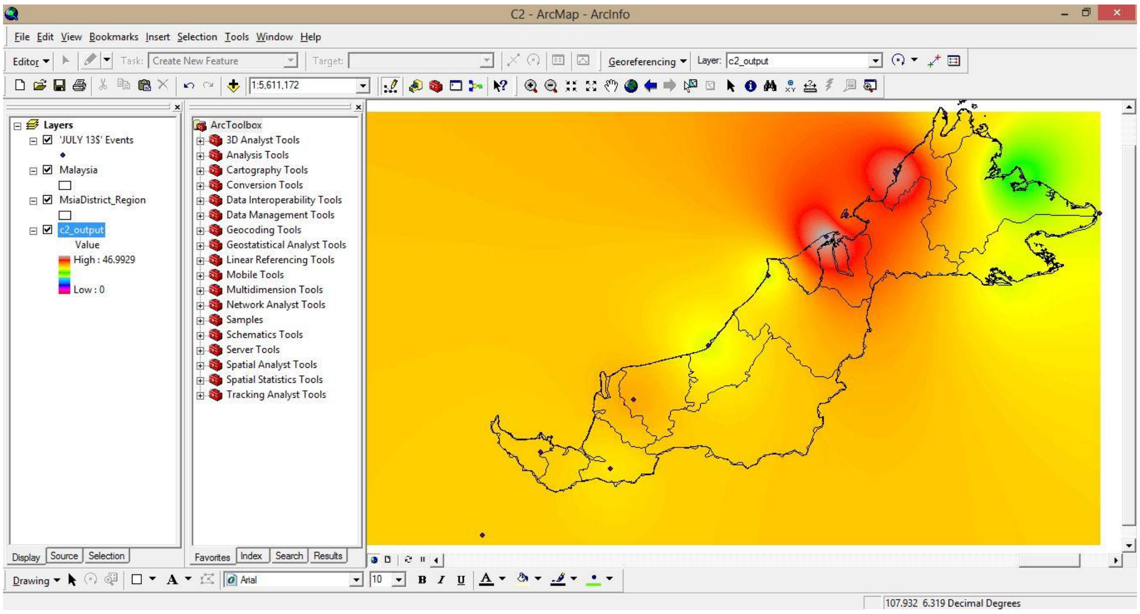
	Temperature, C			Dew Point, C			Humidity			Sea Level Pressure, hPa			Wind Speed, km/h			
Miri	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Events**	**WindDirDegrees**
10/19/2014	33	28	24	28	24	23	94	85	67	1011	1009	1007	16	6	Rain-Thunderstorm	102
10/20/2014	33	28	23	28	24	23	94	83	62	1011	1009	1007	14	8	Rain	106
10/21/2014	33	29	24	28	24	23	94	82	64	1012	1011	1009	19	8	Rain-Thunderstorm	119
10/22/2014	33	29	25	28	25	23	94	84	67	1012	1010	1008	13	6	Thunderstorm	115
10/23/2014	33	29	24	28	25	23	100	85	66	1012	1010	1008	19	8	Rain-Thunderstorm	121
10/24/2014	33	28	23	28	25	23	94	85	69	1012	1010	1008	13	8	Rain-Thunderstorm	125
10/25/2014	32	28	24	27	25	23	94	84	68	1012	1010	1009	37	8	Thunderstorm	87
10/26/2014	32	28	25	28	26	24	100	88	72	1013	1011	1009	19	8	Rain-Thunderstorm	169
10/27/2014	33	28	24	28	26	24	100	85	67	1012	1010	1007	13	6	Rain-Thunderstorm	162
10/28/2014	33	28	24	28	25	23	94	86	25	1011	1009	1007	142	8	Rain-Thunderstorm	127
10/29/2014	33	29	24	27	24	23	94	84	62	1013	1010	1008	27	8	Rain	132
10/30/2014	32	28	24	26	24	22	94	81	63	1012	1010	1008	11	5		188
10/31/2014	33	28	24	27	24	23	94	79	60	1011	1008	1006	10	5		92

APPENDIX C



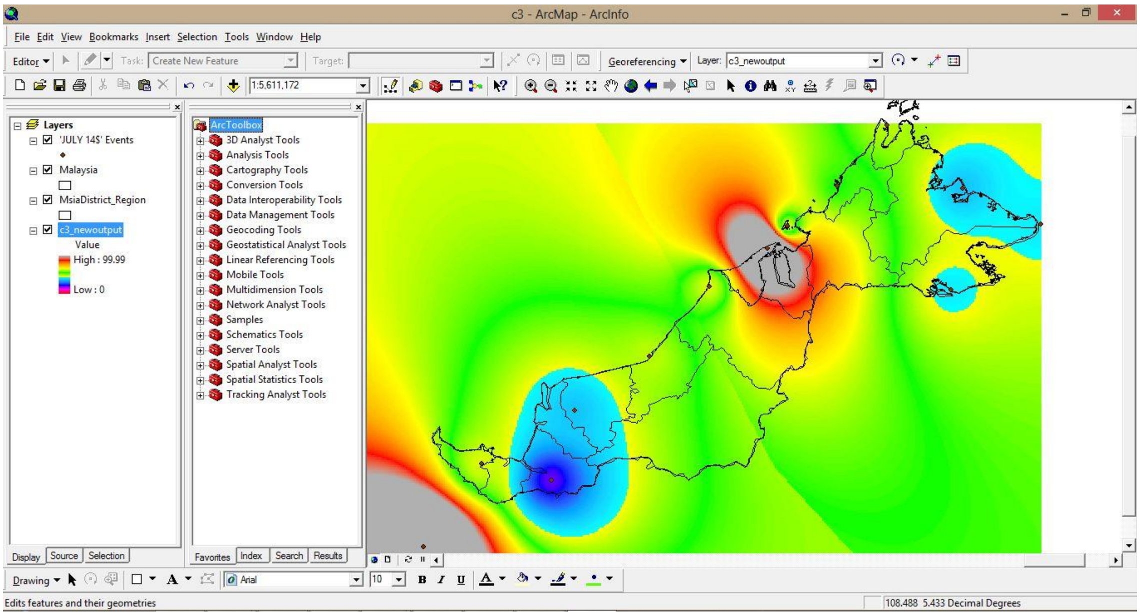
FID	Shape *	Location	Latitude__	Longitude	13_Oct
0	Point	BRUNEI	4.94	114.93	42
1	Point	PONTIANAK	0.15	109.4	63
2	Point	KUCHING	1.48	110.33	32
3	Point	LABUAN	5.3	115.25	30
4	Point	KUDAT	6.92	116.84	30
5	Point	MIRI	4.32	113.99	21
6	Point	KK	5.94	116.05	40
7	Point	BINTULU	3.2	113.03	26
8	Point	SANDAKAN	5.9	118.06	30
9	Point	SIBU	2.33	111.83	35
10	Point	TAWAU	4.27	117.88	27
11	Point	SRIAMAN	1.22	111.45	30
12	Point	X	5.32	119.32	27

APPENDIX D



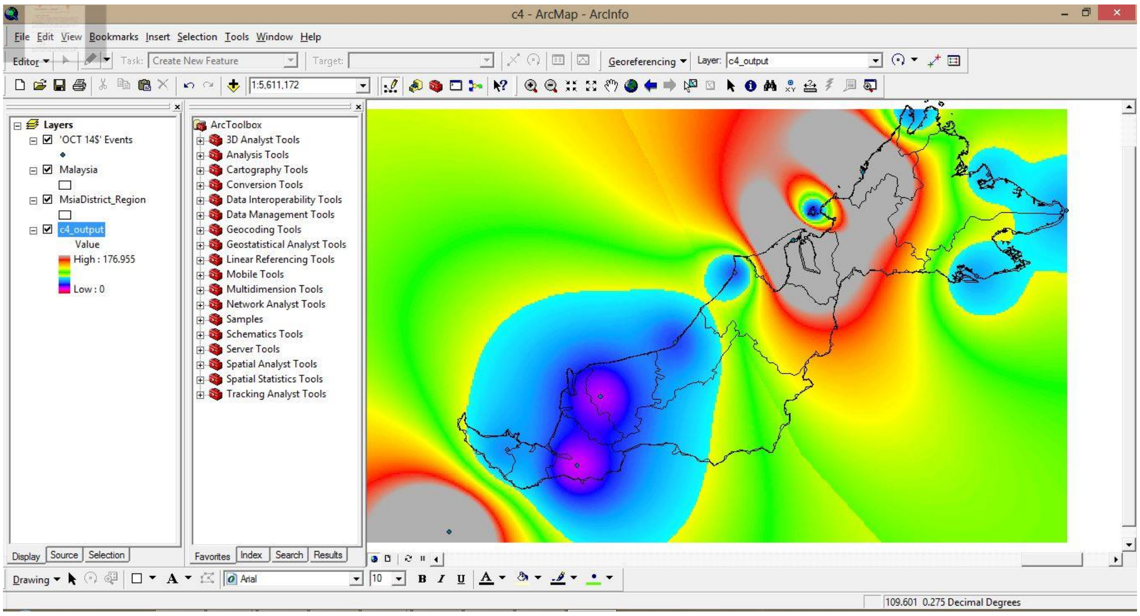
FID	Shape *	LOCATION	LATITUDE	LONGITUDE	13_Jul
0	Point	BRUNEI	4.94	114.93	47
1	Point	PONTIANAK	0.15	109.4	35
2	Point	KUCHING	1.48	110.33	35
3	Point	LABUAN	5.3	115.25	40
4	Point	KUDAT	6.92	116.84	34
5	Point	MIRI	4.32	113.99	32
6	Point	KK	5.94	116.05	45
7	Point	BINTULU	3.2	113.03	32
8	Point	SANDAKAN	5.9	118.06	27
9	Point	SIBU	2.33	111.83	37
10	Point	TAWAU	4.27	117.88	32
11	Point	SRI AMAN	1.22	111.45	34
12	Point	X	5.32	119.32	32

APPENDIX E



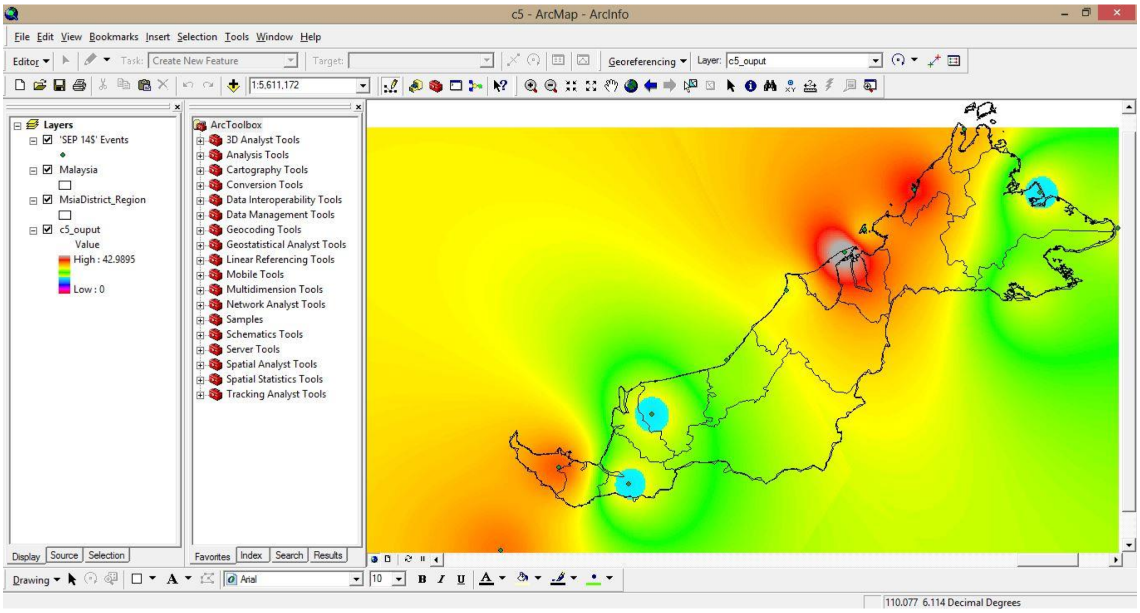
FID	Shape *	LOCATION	LATITUDE	LONGITUDE	14_Jul
0	Point	BRUNEI	4.94	114.93	100
1	Point	PONTIANAK	0.15	109.4	100
2	Point	KUCHING	1.48	110.33	29
3	Point	LABUAN	5.3	115.25	29
4	Point	KUDAT	6.92	116.84	30
5	Point	MIRI	4.32	113.99	29
6	Point	KK	5.94	116.05	34
7	Point	BINTULU	3.2	113.03	30
8	Point	SANDAKAN	5.9	118.06	24
9	Point	SIBU	2.33	111.83	24
10	Point	TAWAU	4.27	117.88	27
11	Point	SRI AMAN	1.22	111.45	14
12	Point	X	5.32	119.32	27

APPENDIX F



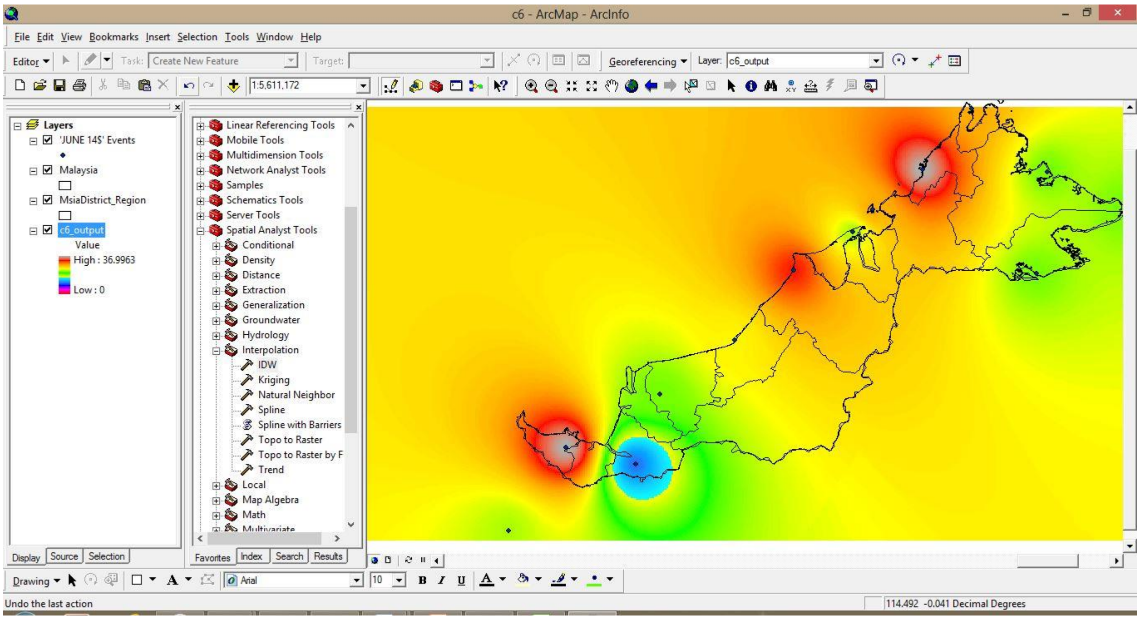
FID	Shape *	LOCATION	LATITUDE	LONGITUDE	oct
0	Point	BRUNEI	4.84	114.93	177
1	Point	PONTIANAK	0.15	109.4	108
2	Point	KUCHING	1.48	110.33	27
3	Point	LABUAN	5.3	115.25	19
4	Point	KUDAT	6.92	116.84	27
5	Point	MIRI	4.32	113.99	24
6	Point	KK	5.94	116.05	142
7	Point	BINTULU	3.2	113.03	23
8	Point	SANDAKAN	5.9	118.06	32
9	Point	SIBU	2.33	111.83	15
10	Point	TAWAU	4.27	117.88	29
11	Point	SRI AMAN	1.22	111.45	14
12	Point	X	5.32	119.32	29

APPENDIX G



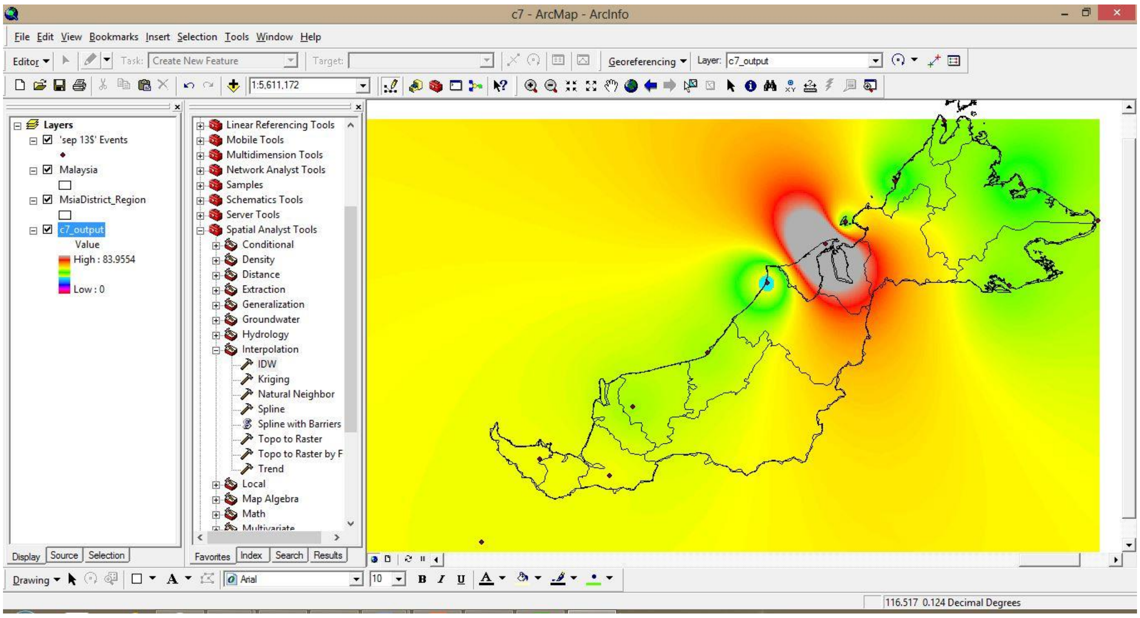
FID	Shape *	LOCATION	LATITUDE	LONGITUDE	14_Sep
0	Point	BRUNEI	4.94	114.93	43
1	Point	PONTIANAK	0.15	109.4	34
2	Point	KUCHING	1.48	110.33	35
3	Point	LABUAN	5.3	115.25	31
4	Point	KUDAT	6.92	116.84	32
5	Point	MIRI	4.32	113.99	28
6	Point	KK	5.94	116.05	37
7	Point	BINTULU	3.2	113.03	26
8	Point	SANDAKAN	5.9	118.06	19
9	Point	SIBU	2.33	111.83	19
10	Point	TAWAU	4.27	117.88	21
11	Point	SRI AMAN	1.22	111.45	19
12	Point	X	5.32	119.32	21

APPENDIX H



FID	Shape *	LOCATION	LATITUDE	LONGITUDE	14_Jun
0	Point	BRUNEI	4.94	114.93	24
1	Point	PONTIANAK	0.15	109.4	24
2	Point	KUCHING	1.48	110.33	37
3	Point	LABUAN	5.3	115.25	29
4	Point	KUDAT	6.92	116.84	29
5	Point	MIRI	4.32	113.99	33
6	Point	KK	5.94	116.05	37
7	Point	BINTULU	3.2	113.03	26
8	Point	SANDAKAN	5.9	118.06	23
9	Point	SIBU	2.33	111.83	23
10	Point	TAWAU	4.27	117.88	23
11	Point	SRI AMAN	1.22	111.45	13
12	Point	X	5.32	119.312	23

APPENDIX I



FID	Shape *	LOCATION	LATITUDE	LONGITUDE	13_Sep
0	Point	BRUNEI	4.94	114.93	84
1	Point	PONTIANAK	0.15	109.4	35
2	Point	KUCHING	1.48	110.33	35
3	Point	LABUAN	5.3	115.25	31
4	Point	KUDAT	6.92	116.84	32
5	Point	MIRI	4.32	113.99	24
6	Point	KK	5.94	116.05	29
7	Point	BINTULU	3.2	113.03	33
8	Point	SANDAKAN	5.9	118.06	29
9	Point	SIBU	2.33	111.83	33
10	Point	TAWAU	4.27	117.88	32
11	Point	SRI AMAN	1.22	111.45	35
12	Point	X	5.32	119.312	33