SPATIAL ANALYSIS ON STRONG WINDS OCCURRENCE IN THE NORTHERN REGION MALAYSIA BASED ON INTERPOLATED WIND SPEED AND WIND DIRECTION MAP

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By

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I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Projek penyelidikan tahun akhir ini mengulas permasalahan pada ciri-ciri kejadian angin kencang di kawasan utara Malaysia. Bulan Oktober tahun 2014 dipilih bertepatan dengan tempoh di mana kejadian puting beliung dilaporkan telah merosakkan harta benda di daerah Pendang, Kedah. Kajian ini dijalankan bertujuan untuk menentukan kesan kelajuan angin dan arah angin pada bulan tertentu yang menyumbang kepada kejadian angin kencang. Data angin yang dikumpul telah diproses dan diinterpolasi untuk menghasilkan peta kelajuan angin dan peta arah angin bertiup menggunakan perisian GIS-Idrisi. Keputusan daripada analisis peta, kelajuan angin yang tertinggi dicatatkan adalah 3.1 m/s pada 4 Oktober 2014 di stesen meteorologi Butterworth. Sementara itu, stesen Pulau Langkawi dan Chuping masing-masing mencatatkan kelajuan angin terendah iaitu sebanyak 0.3 m/s pada 10 Oktober dan 23 Oktober 2014. Peta kelajuan angin dan arah angin yang diplot jelas menunjukkan wilayah angin bertiup, di mana arah tiupan angin ditunjukkan oleh anak panah dan halaju angin diwakili oleh warna-warna yang berterusan. Keputusan yang diperolehi turut membolehkan peta kontur dihasilkan pada peta negeri-negeri utara Malaysia. Perhubungan statistik antara kelajuan dan arah angin diilustrasikan melalui carta garis, peta raster dan gambar rajah rose angin yang menunjukkan kelajuan dan arah angin. Hasil kajian ini adalah penting bagi menunjukkan kepentingan kelajuan dan arah angin dalam merekabentuk struktur bangunan yang mengambil kira rintangan angin kencang.

ABSTRACT

This final year research project reviews the problem on the characteristics of the strong winds occurrence in the northern region Malaysia. The specific month i.e. October 2014 was selected that coincides with the period where the tornado outbreak was reported to damage properties in Pendang district, Kedah. The study was intended to determine the effect of the wind speed and wind direction on that specific month that contributes to the strong wind occurrences. The wind data collected were processed and spatially interpolated to produce wind speed and wind direction map using GIS-IDRISI software. From the map analysis, the highest wind speed recorded was 3.1 m/s on the 4th October 2014 at Butterworth meteorological station. Meanwhile, Pulau Langkawi and Chuping stations have recorded the calmest wind speed of 0.3 m/s on 10th October and 23rd October respectively. The plotted wind speed and wind direction maps were able to show clearly the territory of the wind blows, where directions are shown by arrows and the wind velocity represented by continuous colours. The results have also produced contoured wind map within the northern region Malaysia. The spatial statistics determines the relationship of wind speed and wind direction and the results were illustrated using line charts, raster wind speed maps and the wind rose diagram represents the wind direction. The outcomes of the study are essential in showing the importance of wind speed and direction parameters in the design of building structures that consider resistance to intense wind.

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LIST OF ABBREVIATIONS

GIS	**G**eographical **I**nformation **S**ystem
RMS	**R**oot **M**ean **S**quare
IDW	**I**nverse **D**istance **W**eighted

CHAPTER 1

INTRODUCTION

1.1 Background

Air may not seem to be harmful as we felt the breeze all the time but during a windstorm, the air really makes its presence known. The wind is simply air in motion, flowing from high atmospheric pressures to low pressures. The wind is described with direction and speed. Its direction is influenced by the Earth’s rotation. The direction of the wind is expressed as the direction from which the wind is blowing. For example, easterly winds blow from east to west, while westerly winds blow from west to east. Winds have different levels of speed, such as ‘breeze’ and ‘gale’, depending on how fast they blow (Weather and Climate Basics, 2013).

Moving anything requires a force. Strong winds are due to a strong pressure gradient force. A pressure gradient is how fast pressure changes over distance. So, when pressure changes rapidly over a small distance, the pressure gradient force is large. Strong winds almost always result from large pressure gradients (whyfiles.org, 2013). Strong winds are the most common means of destruction associated with hurricanes that sometimes can uproot trees, knock over buildings and homes, fly potentially deadly debris around, sink or ground boats, and flip cars.

In Malaysia, the characteristic features of the climate are uniform temperature, high humidity, and copious rainfall. Though the wind over the country is generally light and variable, there are, however, some uniform periodic changes in the wind flow patterns. Based on these changes, four seasons can be distinguished, namely, the southwest monsoon, northeast monsoon and two shorter periods of inter-monsoon seasons. The southwest monsoon season is usually established in the latter half of May or early June and ends in September. The prevailing wind flow is generally southwesterly and light, below 15 knots. The northeast monsoon season usually commences in early November and ends in March. During this season, steady easterly or northeasterly winds of 10 to 20 knots prevail. The winds over the east coast states of Peninsular Malaysia may reach 30 knots or more during periods of strong surges of cold air from the north (cold surges). During the two intermonsoon seasons, the equatorial trough (i.e. low atmospheric pressure) lies over Malaysia (MMD, 2012).

The world we are living in undergoes continuous transformation and evolution. The necessity of getting fast access to information and finding fast answers to more and more complex questions led to the development of many activity areas. One of the areas excessively developed lately is that of the Geographic Information Systems (GIS) (Cristea and Jocea, 2016). GIS is a computer-based technology and methodology to collect, store, manipulate, retrieve and analyze spatial data or georeferenced data. GIS requires vast amount of data before the data is converted into information (Elangovan, 2006). Weather data are generally recorded at point locations, therefore estimating data values at other locations requires some form of spatial interpolation when there are limited number of meteorological stations in Malaysia. Spatial interpolation using Geographical Information System can estimate wind speed and direction for a specific location. A variety of interpolation methods are available but accuracy varies among methods depending on the spatial attributes of the data.

This study is intended to explore the Inverse Distance Weighting spatial interpolation method in estimating continuous wind speed and wind direction at the specific date of strong wind occurrence in Pendang, Kedah. The interpolation area will include meteorological stations in four northern region states in Malaysia i.e. Perlis, Kedah, Pulau Pinang and Perak.

This project can contribute in the wind hazard damages study in Malaysia that describes wind speed and direction as the significant contributing factor in the weather forecast of hazards. Prior to any structure and infrastructure construction, it is important to determine the wind direction and wind speed at their location so that the proposed designed will have higher resistance to the wind speed. Consequently, it prevents or reduces wind hazard damages that might occur for any specific location.

1.2 Problem Statement

The wind is moving air and is caused by differences in air pressure within our atmosphere. High-pressure air moves towards low-pressure areas and the speed of air flows depends on the pressure difference. Tornado, typhoon, hurricane are the most powerful, unpredictable and destructive weather hazards on Earth. They occurred in unusually violent thunderstorms when there are sufficient instability and wind shear present in the lower atmosphere. Instability refers to unusually warm and humid conditions in the lower atmosphere and possibly cooler than usual conditions in the upper atmosphere (WeatherQuestion.com, 2013).

Figure 1.1 shows the tornado image caught on camera in Pendang, Kedah. The strong wind occurrence that happened on 14th October 2014 was due to the cumulonimbus cloud formation process and the transition of monsoon winds that caused instability of the atmosphere. As the monsoon winds changes, the atmosphere is unstable and formations of cumulonimbus clouds easily appear. In the 4pm incident, at least 15 houses in Pendang were reportedly damaged by the twister, which also blew the roof of a school, according to Berita Harian. The strong winds blew off the roofs of some houses in a village, while many trees were uprooted. Lamp posts and electricity cables also came crashing down. However, this tornado incident only involved property damage without any loss of life (Tan, 2014).

The research questions that this project intended to answer is whether strong wind occurrence can be detected through daily wind speed and direction data that is spatially modeled through spatial interpolation processes. In addition, this project attempts to determine the spatial relationship of periodic wind data and the effectiveness of spatial interpolation algorithm namely the Inversed Distance Weighted in wind study.

Figure 1.1: Tornado Caught on Camera in Pendang, Kedah on 14 October 2014 (MalaysiaZINE, 2014)

1.3 Objectives

The objectives of this research are:-

1) To analyze the raw data on wind speed and wind direction from 8 meteorological stations for a specific strong wind occurrence in the northern region of Peninsular Malaysia.
2) To evaluate the Inverse Distance Weighted (IDW) spatial interpolation algorithm in deriving average wind speed and wind direction maps over the period of strong winds occurrence.
3) To determine the spatial correlation of the generated wind speed and wind direction map over the specific period of study.

1.4 Scope of Work

This project was carried out within the period allocated by the school beginning September 2016 to June 2017. The main purpose of this study is to establish the relationship between wind speed and wind direction on a strong winds event by using spatial modeling approach. The data used in this study was obtained from Malaysian Meteorological Department for eight main meteorological stations located within the northern region of Malaysia. The recorded data is displayed hourly and statistical analysis was carried out to find the average wind speed and wind direction daily on four different dates for comparison purpose. The data analyzed was transferred and displayed in GIS data format. The readings of wind speed and wind direction data of the eight stations are spatially interpolated using IDW method in GIS IDRISI software.

1.5 Dissertation Outline

Chapter 1 presents the introduction to the research background, gives an overview of the historic strong winds occurrence in Pendang, Kedah on 14th October 2014, objectives of the study and GIS software used for the spatial analytical modeling. In addition, it also provides the scope of work for this study.

Conversely, chapter 2 highlights the literature review of the previous study on wind speed and wind direction. In this chapter, detail explanation regarding the wind such as definition, characteristic of wind was discussed. In addition, this chapter also discussed IDW technique as well as GIS software.

Chapter 3 contained the details of methods and techniques involved in this study to achieve the research objective. In addition, the step uses to prepare data using GIS software is also justified.

Chapter 4 discusses on the result of the research study performed. This includes the result of the spatial interpolation of wind speed and wind direction of the northern region Malaysia on the strong winds occurrence date.

The final Chapter 5 presents the conclusion and benefits obtained from this research. Likewise, some recommendations are suggested in this chapter for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The earth's atmosphere can be modeled as a gigantic heat engine. It extracts energy from one reservoir (the sun) and delivers heat to another reservoir at a lower temperature (space). In the process, work is done on the gasses in the atmosphere and upon the earth-atmosphere boundary. There will be regions where the air pressure is temporarily higher or lower than average. This difference in air pressure causes atmospheric gasses or the wind to flow from the region of higher pressure to that of lower pressure (Johnson, 2001).

There are several variables that affect wind formation, including the earth's rotation and solar energy from the sun. The sun heats up water masses, such as seas and oceans, at a slower rate than their adjacent landmasses. This is because water has a higher specific heat, which is the amount of heat per unit mass necessary to increase its temperature. The warmer land heats up the air above it, causing it to become less dense than the air above the water. What results from this is an air pressure difference between the land and water masses, causing denser air from the sea to flow inland. Something similar happens on the larger scale. Since less solar energy is deposited in the polar region than at the equator, air near the surface of the equator become less dense than at the poles, leading to airflow from polar region to the equator (Segal S, 2013). Wind speed and direction is of general interest to most people but for certain disciplines, wind information is of critical importance. Wind disasters are responsible for the tremendous physical destruction, injury, loss of life and economic damage (Marchigiani, 2013).

GIS is widely used since geographic problems require spatial thinking. The handling of spatial data usually involves processes of data acquisition, storage, maintenance, analysis, and output. For many years, this was accomplished using analog data sources, manual processing and the production of paper maps. The introduction of modern technologies has led to an increased use of computers and information technology in all aspects of spatial data handling. The software technology used in this domain is geographic information systems. The current digital and analog electronic devices facilitate the inventory of resources and the rapid execution of arithmetic or logical operations. These information systems are undergoing much improvement and they are able to create, manipulate, store and use spatial data much faster and at a rapid rate as compared to conventional methods.

2.2 Characteristics of Wind

2.2.1 Wind Speed

Wind speed or wind velocity is a fundamental atmospheric rate. Wind speed is affected by a number of factors, operating on varying scales (from micro to macro scales). Among them are the pressure gradient, the Rossby waves and jet streams, and local weather conditions. There are also links between wind speed and wind direction, notably with the pressure gradient and surfaces where the air is to be found over. The pressure gradient is a term to describe the difference in air pressure between two points in the atmosphere or on the surface of the Earth. It is vital to wind speed, because the greater the difference in pressure, the faster the wind flows (from the high to low pressure) to balance out the variation. The pressure gradient, when combined with the Coriolis effect and friction influences the strong wind direction (Rossby waves) in the upper troposphere. These occurs on a global scale and move from West to East (hence being known as Westerlies). Local weather conditions play a key role in influencing wind speed, as the formation of hurricanes, monsoons or cyclones as freak weather conditions can drastically affect the velocity of the wind (Bhatia, 2014).

Wind speed is normally measured by a cup anemometer consisting of three or four cups, conical or hemispherical in shape, mounted symmetrically about a vertical spindle. The wind blowing into the cups causes the spindle to rotate. In standard instruments, the design of the cups is such that the rate of rotation is proportional to the speed of the wind to a sufficiently close approximation. A wide range of anemometer types is available commercially that vary in size, quality, and sensitivity. In general, smaller anemometers with light cups and quality bearings are used for detailed measurements close to the surface (Anthony and Athol, 2009). Wind speed normally increases with height above the earth's surface and is much affected by such factors as the roughness of the ground and the presence of buildings, trees and other obstacles in the vicinity (Harrison, 2014).

The Beaufort scale was the earliest system used for estimating wind speeds. It was introduced in 1806 by Admiral Sir Francis Beaufort (1774-1857) of the British navy to describe wind effects on a fully rigged man-of-war sailing vessel, and it was later extended to include descriptions of the effect on land features as well. The Beaufort scale is divided into a series of values, from 0 for calm winds to 12 and above for hurricanes (Jeffers, 2004). Each value represents a specific range and classification of wind speeds with accompanying descriptions of the effects on surface features, as shown in Table 2.1.

Table 2.1: The Beaufort Scale (Jeffers, 2004)

Beaufort Scale	Classification	Wind Speed (km/hr)	Effects of Surroundings
0	calm	0	Smoke rises vertically.
1	light air	2 – 5	Smoke drift indicates wind direction.
2	light breeze	6 – 12	Wind felt on face; leaves rustle.
3	gentle breeze	13 – 20	Leaves, small twigs in constant motion.
4	moderate breeze	21 – 30	Dust and leaves raised up, branches move.
5	fresh breeze	31 – 40	Small trees begin to sway.
6	strong breeze	41 -50	Large branches of trees in motion/
7	moderate gale	51 – 61	Whole trees in motion; resistance felt walking against the wind.
8	fresh gale	62 – 74	Twigs and small branches break from trees.
9	strong gale	75 – 89	Larger branches break from trees.
10	whole gale	90 – 103	Trees broken and uprooted.
11	storm	104 – 119	Widespread damage.
12	hurricane	120 +	Violence and destruction.

2.2.2 Wind Direction

Wind direction is measured by a vane consisting of a thin horizontal arm carrying a vertical flat plate at one end with its edge to the wind. At the other end, there is a balance weight that serves as a pointer. The arm is carried on a vertical spindle mounted on bearings which allow it to turn freely in the wind. The anemometer and wind vane (Figure 2.1) are each attached to a horizontal supporting arm at the top of a 10 m mast (MetOffice.gov.uk, 2015). Wind direction is measured relative to true north (not magnetic north) and is reported from where the wind is blowing. An easterly wind blows from the east or 90 degrees, a southerly from the south or 180 degrees and a westerly from the west or 270 degrees (Harrison, 2015).

Figure 2.1: Anemometer and Wind Vane (MetOffice.gov.uk, 2015)

Regardless of the geographic scale and area, there are three primary forces which contribute to the cause of wind direction. They are pressure, Coriolis effects, and friction. Blowing from high to low pressure, air always attempts to balance out the pressure levels. A high-pressure system next to a low-pressure system will cause wind direction to flow clockwise outwards toward a low-pressure system. The low-pressure system is what causes wind direction to flow counterclockwise and inward. This is also referred to as a cyclonic flow. The phenomenon of the Coriolis effects is defined by the

National Weather Service as allowing the "calculation of the apparent effects on moving bodies when viewed from a rotating Earth" (Shepard, 2008). It is not really a force, though its actions resemble one. Greater Coriolis effect is seen closer to the pole regions, and in the southern hemisphere, this deflection is to the left. Extremely small scales diminish the Coriolis effect, but it is a huge factor in mid-latitude systems' wind direction. Accelerating speed will increase deflection.

The final cause of wind direction is friction. Surface-level winds are mostly influenced by friction, as this is where the wind encounters varying surfaces. If the wind blows into a building, it must cause a change in direction. It could rise above the building or go around it in either direction, but it will cause a wind direction change. Slowing down of winds by a rougher surface will also decrease Coriolis deflection, and acceleration over a smoother surface will cause the opposite (Shepard, 2008).

2.2.3 Strong Wind (Tornadoes)

Strong winds are most often caused by air moving from an area of high atmospheric pressure to an area of low pressure quickly over a small distance. This is called a strong pressure gradient force. Even light winds are normally caused by air moving between areas of different pressures. A pressure gradient represents how quickly the atmospheric pressure changes over a space. What the wind blows over can also have an impact on its speed. Open areas, such as lakes, experience faster winds than a forest does. The trees in the forest help slow the wind down by friction. When a solid object such as buildings are hit with the wind, they can funnel the wind between them and cause the wind to gain speed.

Thunderstorms also have the ability to create strong winds. Rain from the storm evaporates below the cloud, causing the air to cool beneath it. This cold air is heavy and heavy and crashes into the ground below. When it hits the ground, this cold air must turn sideways, and the result is strong winds (whyfiles.org, 2013). According to Jessa (2016), cumulonimbus clouds are a type of cumulus cloud associated with thunderstorms and heavy precipitation. They are dense, vertical, towering clouds commonly associated with instability in the atmosphere and thunderstorms. The cumulonimbus cloud is formed by water vapor that air currents carry upwards, and these clouds can produce dangerous lightning and severe tornadoes.

A tornado is a narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground. Tornadoes develop from severe thunderstorms in warm, moist, unstable air along and ahead of cold fronts. Since the wind is invisible, it is hard to see a tornado unless it forms a condensation funnel made up of water droplets, dust, and debris. There are two types of tornadoes, those that come from a supercell thunderstorm and those that do not (Folger, 2011). According to Folger, tornadoes that come from a supercell thunderstorm are the most common, and often the most dangerous. In supercell thunderstorm, a rotating updraft is essential to the development of a tornado. Rotation of the updraft can be caused by wind shear, which occurs when winds at two different levels above the ground blow at different speeds or in different directions. Non-supercell tornado forms from a vertically spinning parcel of air near the ground that is caused by wind shear from warm, cold or sea breeze front or from a dryline (the interface between warm, moist air and hot dry air). When an updraft moves over the spinning parcel of air and stretches it, a tornado can form.

One non-supercell tornado is the gustnado, a whirl of dust or debris at or near the ground with no condensation funnel, which forms along the gust front of a storm. Another non-supercell tornado is a landspout. A landspout is a tornado with a narrow, rope-like condensation funnel that forms while the thunderstorm cloud is still growing and there is no rotating updraft - the spinning motion originates near the ground. Waterspouts are similar to landspout, except they occur over water. Their differences are explained in Figure 2.2.

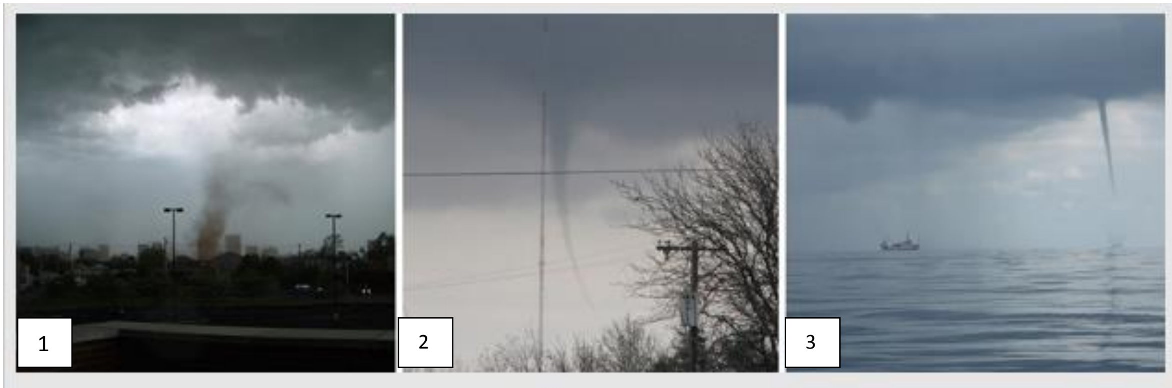

Figure 2.2: Gustnadoes (1), Landspouts(2), and Waterspouts (3)
(NOAA National Severe Storms Laboratory)

2.3 Geographic Information System (GIS)

2.3.1 History of GIS

Mapping has revolutionized how we think about location. Maps are important decision-making tools. They help us get to places and becoming more immersed in our everyday lives. Advancements in GIS were the result of several technologies. Databases, computer mapping, remote sensing, programming, geography, mathematics, computer-aided design, and computer science all played a key role in the development of GIS (GIS Geography, 2017).

A GIS is a modern extension of traditional cartography with one fundamental similarity and two essential differences. The similarity lies in the fact that both a cartographic document and a GIS contain examples of a base map to which additional data can be added. The differences are that there is no limit to the amount of additional data that can be added to a GIS map and secondly the GIS use analysis and statistics to present data in support of particular arguments which a cartographic map cannot do. Cartographic maps are often extremely simplified as there are limits to the amount of data that can be physically and meaningfully stored on a small map (Dempsey, 2012).

The wind speed and wind direction analysis in this study use the GIS IDRISI Selva software. IDRISI is an integrated feature-rich software system for the analysis and display of spatial data includes tools for GIS, image processing, surface analysis, vertical applications for land change analysis and earth trends exploration and more. The Selva Edition released in January 2012, is the 17th version of the IDRISI Software since 1987. The IDRISI software includes a comprehensive suite of image processing tools, making it an excellent choice for land cover mapping applications with remotely-sensed data. Tools are provided for image restoration, enhancement, classification and transformation (Clark Labs, 2012).

2.3.2 Characteristic of GIS (Data Types & Data Models)

Faridi (2008) explained that the terms data and information are often used indiscriminately. However, both have a specific meaning. Data can be described as different observations, which are collected and stored. Information is that data, which is useful in answering queries or solving a problem. Map making is an old art but digitizing a large number of maps provides a large amount of data after hours of painstaking works, but the data can only render useful information if it is used in the analysis.

There are two types of GIS data namely the attribute data and spatial data. Elangovan (2008) stated that spatial data means data which are referenced to earth. Maps, satellite imageries, aerial photographs are an example of spatial data whereas the attribute data are attached to spatial data and called as non-spatial data. The attributes refer to the properties of spatial entities. They are often referred to as non-spatial data since they do not in themselves represent location information. This type of data describes characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature. Attribute data is often referred to as tabular data. Spatial data is a geographical representation of features. To specify the position in an absolute way, a coordinate system is used. For small areas, the simplest coordinate system is the regular square grid. For larger areas, certain approved cartographic projections are commonly used. Internationally there are many different coordinate systems in use. This location information is provided in maps by using points, lines, and polygons. These geometric descriptions are the basic data elements of a map. Thus spatial data describes the absolute and relative location of geographic features (Faridi, 2008). Spatial data can further be divided into two model i.e. vector and raster data model as described in Figure 2.3.

1) Vector Data

Vector data represents any geographical feature through point, line or polygon or a combination of these (Samvedan, 2007).

i. Point

A point in GIS is represented by one pair of coordinates (x & y). It is considered as a dimensionless object. Most of the times a point represent the location of a feature (like cities, wells, villages etc.).

ii. Line

A line or arc contains at least two pairs of coordinates (say- x1, y1 & x2, y2). In other words, a line should connect minimum two points. Start and end points of a line are referred as nodes while points on curves are referred as vertices. Points at intersections are also called as nodes. Roads, railway tracks, streams etc. are generally represented by a line.

iii. Polygon

In simple terms, the polygon is a closed line with the area. It takes minimum three pairs of coordinates to represent an area or polygon. The extent of cities, forests, land use etc. is represented by a polygon.

2) Raster Data

Raster data is made up of pixels. It is an array of grid cells with columns and rows. Each and every geographical feature is represented only through pixels in raster data. There is nothing like point, line or polygon. If it is a point, in raster data it will be a single pixel, a line will be represented as a linear arrangement of pixels and an area or polygon will be represented by contiguous neighboring pixels with similar values. In raster data, one pixel contains only one value (unlike vector data where a point, a line or a polygon may have a number of values or attributes) meaning only one geographical feature can be represented by a single set of pixels or grid cells. Hence a number of raster layers are required if multiple features are to be considered for example land use, soil type, forest density, topography etc. (Samvedan, 2007).

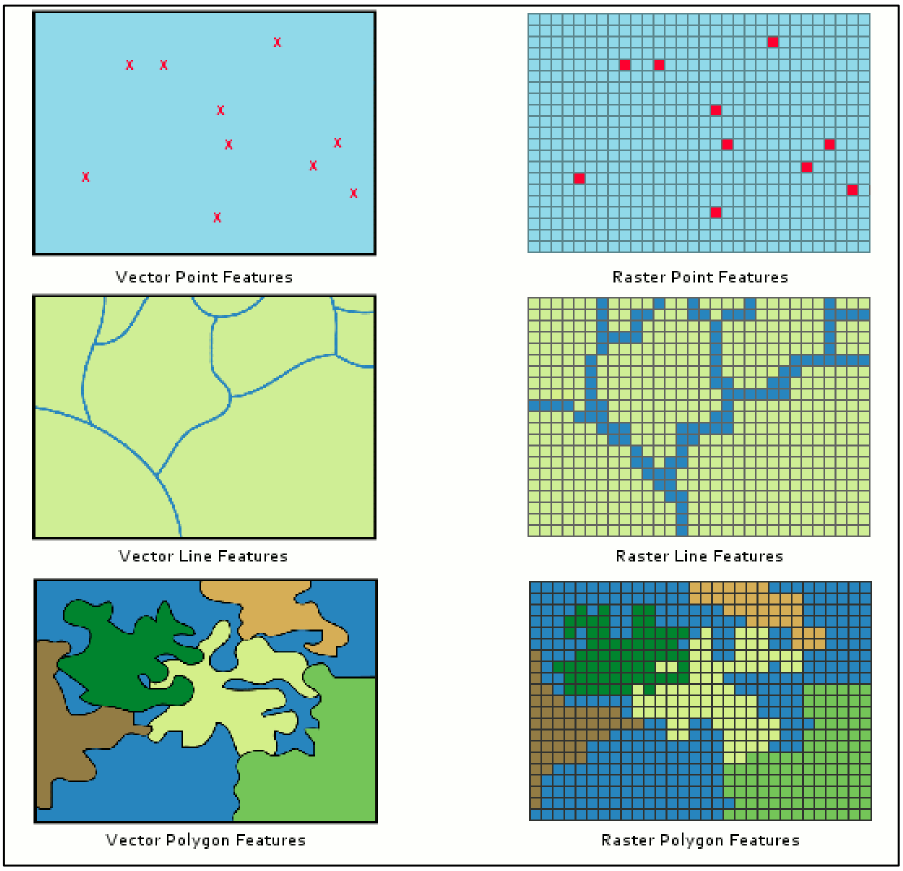

Figure 2.3: Computer Representations of Geographic Features (GISInfo, 2013)

The visual differences between vector and raster data as displayed in GIS software are described in Figure 2.4. One just cannot visualize the differences when raster data are prepared on high-resolution image (megapixels). Therefore, both data model have balance merits and demerits with respect to the GIS application and spatial analysis.

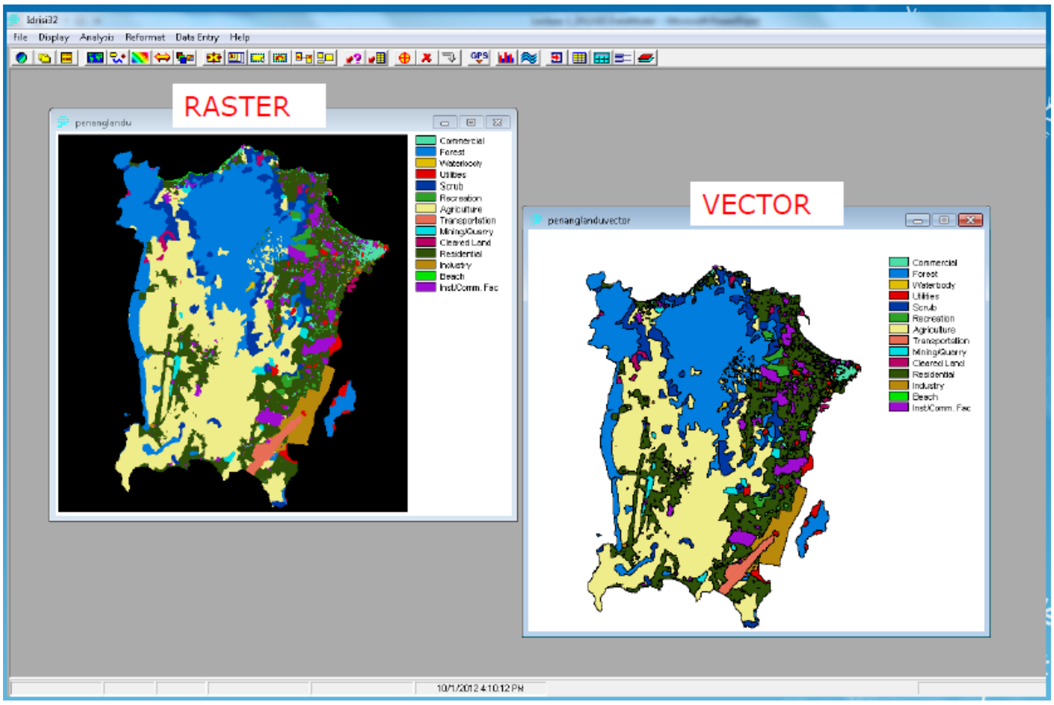

Figure 2.4: Visual Difference between Raster and Vector Map
(Ahamad, 2016)

2.3.3 Function of GIS

Geographic information systems have been adopted as a useful tool by a wide range of disciplines such as environmental planning, property management, infrastructure, sitting, emergency planning, automobile navigation systems, urban studies, market analyses, and business demographics. Analyses from GIS can determine both threats and opportunities for development (Rachel, 2007). Developed countries are using GIS widely in many areas but developing countries are moving towards the development of GIS database for their resources.

GIS can be defined as a computer-based tool that analyses, stores, manipulates and visualizes geographic information on a map. A GIS lets us visualize, question, analyze and interpret data to understand relationships, patterns, and trends (Williams and Robert, 1987). In GIS, data is connected with geography. The data will be comprehensible when it relates to other things. GIS maps are intelligent. It has many advantages compared with a paper map in this digital age. With the help of a GIS, the maps can be stored in digital form in a database in world coordinates (meters or feet). This makes scale transformations unnecessary, and the conversion between map projections can be done easily with the software. Remote sensing, aerial photography, cartography, surveying and other field instruments for attribute data collection contributes to the data acquisition. Cartography, surveying, geography and geodesy contribute to mapping process (Elangovan, 2006). The usage of GIS analytical tool such as GIS-IDRISI software can reduce cost and time spent on this study as it is the solution to address the experimental problem.

The various spatial analysis functions provided GIS are applicable in performing many planning tasks. This can speed up the process and allows for easy modifications to the analysis approach. Toggweiler and Key (2001) stated that spatial interpolation is more worthwhile if a sufficient density of weather stations is available across the study area. The density of the network required depends upon the variable to be estimated. Wind speed, for example, is more variable over shorter distances than temperature or relative humidity, and hence would be expected to require a denser network of monitoring sites to achieve accurate and precise interpolated surfaces. Spatial interpolation is often an important strategy for creating a continuous surface when taking irregular point data (Kane, 2009). The rules about the spatial variation and location of data collection points are significant because they can greatly affect the results (Andrews et al., 2002).

2.3.4 Inverse Distance Weighted Spatial Interpolation Technique

One of the most frequently used deterministic models in spatial interpolation is the inverse-distance weighting (IDW) method. It is relatively fast and easy to compute, and straightforward to interpret. Its general idea is based on the assumption that the attribute value of an unsampled point is the weighted average of known values within the neighbourhood, and the weights are inversely related to the distances between the prediction location and the sampled locations. The inverse distance weight is modified by a constant power or a distance-decay parameter to adjust the diminishing strength in a relationship with increasing distance (George and David, 2006).

Distance-based weighting methods have been used widely to interpolate climate data. The values that closer to the unsampled location are more representative of the value to be estimated than the samples that further away from this assumption (Luo et al., 2008). Interpolation refers to the process of estimating the unknown data values for specific locations using the known data values for other points. In general the more sample points we have the better. Likewise, it is best to have a good spread of sample points across the study area. The spatial arrangement of those points can take different forms.

The principle of IDW methods is to assign more weight to nearby points than to distant points. According to Luo et al. (2008), the measured point that is closest to the prediction point will give the best prediction as compared to the furthest point. IDW has the advantage and disadvantage itself. It is simple and quick to calculate but it is easily affected by uneven distributions of observational data and commonly has a 'bird-eyes' pattern around a solitary data point with the values that differ from the surrounding. Luo et al. (2008) have studied the interpolation of wind speed using IDW and found that IDW consistently adheres to the original wind speed range of the data.

2.4 Statistical Analysis

The field of statistics touches our lives in many ways. From the daily routines in our homes to the business of making the greatest cities run, the effect of statistics is everywhere. Traditional methods for statistical analysis of sampling data to interpreting results have been used by scientists for thousand years. But today’s data volumes make statistics ever more valuable and powerful. Affordable storage, powerful computers, and advanced algorithms have all led to an increased use of computational statistics. Large data volumes or running multiple permutations of calculation can be worked out using statistical computing.

Statistical analysis can be defined as the science of collecting, exploring and presenting large amounts of data to discover underlying patterns and trends (Smith B., nd). Statistics has been a routine application in research work, industrial activity, and government management and has become more scientific for daily decision making that needs to be made.

Climatology was originally a sub-discipline of geography and was therefore mainly descriptive. Description of the climate consisted primarily of estimates of its mean state and estimates of its variability about that state, such as its standard deviations and other simple measures of variability. Much of climatology is still focused on these concerns today. The main purpose of this description is to define ‘normal’ and ‘normal deviations’, which are eventually displayed as maps. These maps are then used for regionalization (in the sense of identifying homogeneous geographical units) and planning. The paradigm of climate research evolved from the purely descriptive approach towards an understanding of the dynamics of climate with the advent of computers and the ability to simulate the climatic state and its variability. Statistics plays an important role in this new paradigm (Storch and Zwiers, 2001).

With the data laid out properly, it is easily and efficiently combined records into groups, pull groups of records apart to examine them more closely, and create charts that give the insight into what the raw numbers are really doing. When the statistics are put into tables and charts, the numbers then can be understood (Carlberg, 2014).

2.5 Summary

The conducted literature review discovers the wind characteristics and how wind speed and wind direction could be measured. Besides that, classification of winds can also be determined by referring to the Beaufort scale that has been used by the British navy to describe wind effects on a fully rigged man-of-war sailing vessel, which was later extended to include descriptions of the effect on land features as well. All the facts regarding the geographic information system such as the history, characteristic and its functions are also clearly described in this chapter. The chosen inverse distance weighted spatial interpolation technique are discussed in detail based on the previous study as well as the statistical analysis in order to interpret and analyse the data for this study.

CHAPTER 3

METHODOLOGY

3.1 Overview

The project methodology in general starts with intensive literature reviews, collects the primary data on wind from Malaysian meteorological stations and statistically process them in Microsoft Excel. Consequently, a spatial database was built to link the wind attributes to the respective meteorological stations in GIS platform. Lastly, the spatial analytical interpolation was performed to generate continuous wind speed and wind direction pertaining to the strong wind occurrences within the event date. From this methodological framework, wind speed and wind direction map of the northern region, Malaysia was produced. Details on the research procedures are explained in the subsequent section.

3.2 Research Procedure

The methodology is the gradual stages in the theoretical analysis that describes the study method used. It starts with the gathering of information until the result of the research is obtained. The methodological steps for this project follow the objectives of the study and are described based on the heuristic steps as in the flowchart depicted in Figure 3.1. The following main steps are:-

1) Project Identification
2) Literature Review
3) Research Method
4) Result and Discussion
5) Conclusion and Recommendation