Wind Speed Modeling for Malaysia

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Abstract- The spatial wind modeling is essential and helpful during early stage of any wind energy project's site selection. The aim of this study was to establish a wind map that described the spatial wind distribution in Malaysia. The objectives of the study were to interpolate spatial wind distribution in Malaysia and followed by to extrapolate the spatial wind distribution to its altitudes. Twelve selected Malaysian Meteorological Department (MMD) stations' wind data were collected; from these, 9 were used for the spatial modeling and another 3 were used for the validation. Spatial wind data were interpolated by Ordinary Kriging. Then, the spatial wind modeling extrapolated the spatial wind data to its altitude which was 10 m height from the elevation by power law approach. Kriging interpolation showed that in Johor or southern parts of Peninsular Malaysia where prevailing wind was higher than other areas along the year. After extrapolation, the wind map showed the wind speed with its longitude, latitude, and altitude coordination. Addition, Kriging interpolation had been improved to present the spatial wind distribution in Malaysia by spatial modeling, extrapolation. Lastly, the accuracy of the Kriging interpolation and wind map were ±1.1143 and ±1.4949 m/s respectively.

Keywords—Spatial modeling, Kriging Interpolation, Wind Resources, GIS, Malaysia.

1. Introduction

Nowadays, computerization and industrialization have been causing the rising of energy demand. Since, industrial revolution began in the late 18th and early 19th centuries. Machines have been substituting human force, causing a significant energy demand to work the machines. Meanwhile, for the last three decades, computer usage has also spread to virtually every kind of workplace. Nevertheless, none of these is possible without electricity. The used of cell phone and computer increased dramatically recent years, rendering increased of the daily energy demand. Today, the Information and Technology (IT) now represents about 10 percent of the world's electricity generation [1]. Moreover, most of our daily used electronic appliances such as television, refrigerator, washing machine, and cell phone are also depended on the electricity in order to be functioned. In short, electricity usage is increasing proportionally with the development of computerization, industrialization, and electronic industrials. The electricity consumption in Malaysia is dramatically increased from 9,090 GWh in year 1980 to 116,937 GWh in year 2010 [2]. Increase in energy demand directly bringing effects to the power generation. Electrical power must be available to the consumer upon demand, and without electrical power; our fast-paced society would come to an inevitable halt [3]. Installed capacity for power generation in Malaysia revealed that 86.8 % is from fossil fuel source, 10.5 % from hydro, 2.6 % from biomass, and other sources is 0.1 %. Before 1980, energy sector in Malaysia is highly relying on a single source of energy - crude oil [4]. Due to its fast depleting supply, crude oil is no longer seen as a feasible source of energy supply in Malaysia. Yet, crude oil and natural gas still dominated the energy supply in Malaysia and are expected to continue to play a major role in primary energy mix [4]. However, the burning fossil fuel may totally deplete in one day. Interrelated estimation showed that fossil fuel deposits will only enough to sustain the energy supply to mankind till 2088 [5]. Therefore, renewable energy development becoming more and more important, more intensive study need to be carried out.

Malaysia is now implementing the five fuel diversification policy in the energy sector, which are natural gas, coal, oil, hydro and renewable energy [4,6,7]. This is critical to ensure that the country is not dependent only on a single source of energy [6,8]. The renewable energy was added to the fuel diversification policy in year 1999 [7]. Renewable energy is no longer a new term for humankind. While, renewable energy is the power generated from replenishes source and will not face the depletion problem. However, renewable energy is only an option for power generation due to the economic cost is higher than fossil fuel [9]. The renewable energy sources implemented in Malaysia are biogas, biomass, small hydro, and solar photovoltaic with a combined capacity of 311.56 MW have been approved by Feed-in Tariff in Malaysia [10]. Nonetheless, today, wind is the fastest growing renewable energy resources in the world [11-13]. Latest technology has developed remarkable advance in wind power design [3]. In ancients, wind power had been used to work out sail boat, water pump and gain grinded, in the earliest of human history [14]. Yet, wind power used to generate electricity start developing when the first large wind machine was installed in Cleveland, Ohio, in the year 1888 [15]. Additionally, India and Thailand had been showed successful on implementing wind energy at the countries where near to Equator areas [13,16]. Therefore, it is now considering including wind under the Feed-in Tariff (FiT) Malaysia [17]. Wind energy exploitation in Malaysia is still in study stage and it is crucial to have a nationwide wind energy assessment study [18,19].

Meso-scale wind maps had been established in some countries such as India, Thailand, and Philippine, by Karlsruhe Atmospheric Mesoscale Model (KAMM) to study the nationwide wind resources [13,20,21]. These KAMM is the method used in Wind Atlas Analysis and Application Program (WAsP) software to establish wind atlas or wind map [21]. However, KAMM was limited by the resolution [21]. Large sizes of the region to be mapped, more parts were needed to be split [20,21].

Environmental data including wind data collected are typically from point sources [22]. For example, wind data obtained from a wind mast is only representing the wind resource within 3 km in radius from a point of an area measured. In other words, another wind mast is required in order to measure wind data more than 3 km from a point. Moreover, a perfect spatial modeling for real-world feature is challengeable [22], widely used is the basic of this modeling i.e. spatial interpolation. Meanwhile, there are certain limitations which are (i) it is difficult to select an appropriate spatial interpolation method for a dataset [22,23]; (ii) spatial interpolation is only presenting the spatial distribution of wind speed in Malaysia; and (iii) wind speed varied at different heights. Therefore, simple spatial interpolation from spatial modeling is not fully representing the real-world feature.

Wind resource presented in image, known as spatial modeling, is easier to be understood. Spatial modeling is a method presenting the wind resources in a compact and informative image. The information carried by a spatial modeling of wind resource is the wind data with geographical coordination. In fact, a spatial wind modeling is essential and helpful during early stage of any wind energy project's site selection. Spatial wind modeling gives clear image for one to analyze and identify potential area for wind energy development. A spatial wind modeling presents the distribution of the wind speed for whole Malaysia. So, this makes the wind speed visualization in term of the spatial distribution. Besides, spatial wind modeling has been reduced the cost of the wind energy exploitation through simulating the wind resource of an area where wind measuring system is absent. This is helpful especially at mountain areas due to that building a wind measurement system at mountain regions is usually difficult and expensive if compare to flat areas [22].

The aim of this study was to establish a wind map that described the spatial wind distribution in Malaysia. The objectives of the study were to interpolate spatial wind distribution in Malaysia and followed by to extrapolate the spatial wind distribution to its altitudes.

Most of the wind energy exploitations were begun with an existing meteorological wind data. Wind data from MMD was the main input data for this study. MMD stations were selected based on outcome of wind resource assessment project started since 2008 at few proposed potential sites. There were three main considerations in selecting the MMD stations to obtain the wind data: First, to select the nearest MMD stations from these potential sites. Second, to select the MMD stations located coastal areas. This was due to the construction cost of wind measurement system at coastal areas is comparatively cheaper than the mountain regions. Third, to select MMD stations located in the interpolation range areas, so that the wind data could be used to validate the spatial wind modeling. 12 selected MMD stations' wind data were collected; from these, 9 were used for the spatial modeling and another 3 were used for the validation. A basic spatial wind modeling was the spatial interpolation. The wind data from the point sources were interpolated to a spatial wind data. Spatial wind data were interpolated by Ordinary Kriging. Then, the spatial wind modeling extrapolated the spatial wind data to its altitude which was 10 m height from the elevation. After extrapolation of the spatial wind data, the wind map could now representing the wind speed at 10 m height followed its elevation. In other words, the wind map showed the wind speed with its longitude, latitude, and altitude coordination. The validation of the spatial interpolation and wind map was done by relating and generating a simple linear regression between the simulated and measured wind data. However, the validation of the wind map was done only for the 10 m height due to the measured wind data were from 10 m height.

2. Methodology

2.1. Study Area and Wind Data

Malaysia is a country that lies entirely in the equatorial zone [24] or equatorial low (Intertropical Convergence Zone – ITCZ) [25]. Asian monsoon, included the weather in Malaysia, is associated with a larger than average seasonal migration of the ITCZ [25]. The weather in Malaysia is characterized by two monsoon regimes and two shorter periods of inter-monsoon seasons, namely, the southwest monsoon from late May to September, and the northeast monsoon from November to March [12,26]. There were some uniform periodic changes in the wind flow patterns based on these four seasonal monsoons [27]. During Southwest monsoon, the prevailing wind flow is generally south-westerly and light, below 7.5 m/s [27]. During Northeast monsoon, steady easterly or north-easterly winds of 5 to 10 m/s prevail, but, at the east coast states of Peninsular Malaysia may reach 15 m/s or more [27]. During the two inter-monsoon seasons, the winds are generally light and variable [27]. Besides, during typical year, high pressure over the eastern Pacific cause warm equatorial water and surface wind to flow westward, then converge near Indonesia [25]. As a result, during the months of April to November, south-westerly winds over the northwest coast of Sabah and Sarawak region may be strengthen to reach 10 m/s or more [27]. Meanwhile, there is a mesoscale wind or local wind affect the wind flow in Malaysia. As Malaysia is mainly a maritime country, the effect of land and sea breeze on the general wind flow pattern is very significant especially during days with clear skies [27]. On bright sunny afternoons or clear nights, sea and land breezes of 5 to 7.5 m/s very often develop and reach up to several tens of kilometers inland or the coastal areas [27]. Similar to the land and sea breeze, daily wind occurs in many mountainous regions are called mountain and valley breeze [25]. Valley breeze is the warm air rise along the mountain slope during the day time, whereas Mountain breeze is the cool air drainage into the valley after sunset [25]. Average wind speed for valley breeze is more than 9 m/s, whereas mountain breeze generally stronger than valley breeze with winds reaching speeds of 11 m/s [28].

At the early stage of wind energy exploitation, existing wind data or secondary wind data are useful in the wind resource assessment. The study area selected was Malaysia, thus wind speed obtained must be in Malaysia. The selected MMD stations are Langkawi, Kuala Terengganu, Mersing, Kuching, Bintulu, Kota Kinabalu, Kudat, Sandakan, Tawau, Cameron Highland, Kuantan, and Kapit. However, the existing wind measurement in Malaysia is limited. Hence, this study was based on meteorological wind data although the meteorological wind measurement systems were not installed for the wind energy exploitation purposes. Various influential studies investigating the impacts of the variability of renewable resources begin with meteorological (met) station data, as this is often readily available over a wide geographic area [29]. Hourly wind data at twelve different stations were obtained from the MMD. For the purpose of interpolation of spatial wind distribution, wind data at nine stations were used, which were Mersing, Kuala Terengganu, Pulau Langkawi, Sandakan, Kudat, Kota Kinabalu, Bintulu, Kuching and Tawau. These nine selected interpolation points represented the wind speed at the coast or flat areas in Malaysia. On the other hand, other wind data from another three stations, Cameron, Kuantan and Kapit, were used for validation. The locations of these twelve MMD monitoring stations were shown in Figure 1.

Figure 1. Location of selected meteorological stations.

2.2. Kriging Interpolation

Kriging interpolation method is categorized into local and geostatistical interpolation method [30,31]. It can be exact or inexact [30]. Kriging is a relatively new statistical technique for interpolating observation [32]. It is often used for applications in soil science and geology [33]. Kriging assumes that the distance or direction between sample points reflects a spatial autocorrelation that can be used to explain variation in the surface [33]. The most common and basic technique for Kriging interpolation is Ordinary kriging [22,33-35]. Ordinary Kriging assumes that there is no constant, mean for the data over an area mean (i.e., no trend) [22,33,34]. Hence, the Kriging equation for Ordinary Kriging is as below [22,31,34]:

$$\hat{z}(x_u) = \sum_{i=1}^{n} \lambda_i z(x_i) \tag{1}$$

where,

$\hat{z}(x_u)$ = the estimated value of an attribute at the point of interest, x_u

$z(x_i)$ = the observed value at the sampled point, x_i

λ_i = Kriging weight

Ordinary Kriging weights come from a semivariogram [34]. Hence, the determination of semivariance must fit to semivariogram to a model before making prediction [34]. Fitting a model to a semivariogram is difficult [31] and each model is designed to fit different types of phenomenon [34]. Spherical and exponential are two common models [34]. Spherical model shows a progressive (equivalently) and exponential model shows an exponentially decrease of spatial auto-correlation with increasing distance [34]. Thus, Spherical model was selected for the spatial interpolation of wind data. Hourly wind data was interpolated to hourly spatial wind data Ordinary Kriging. The mean of hourly spatial wind data collected within a month represented the monthly spatial wind data.

2.3. Extrapolation of Wind Map

In the previous section, spatial wind data had been interpolated and a spatial wind distribution for whole Malaysia was presented in the xy-coordinate. Meanwhile, in this section, wind map was established to present the spatial wind distribution for whole Malaysia at its xyz-coordinate. Power law extrapolation approach and the Digital Elevation Model (DEM) were used to establish the spatial wind distribution with its xyz-coordinate.

The power law is the approach used by many wind energy researcher to extrapolate the varies wind speed with height and altitude in the atmospheric boundary layer [36-38]. Figure 2 shows the extrapolation of wind map or spatial wind modeling was depicted. v is the wind map (xyz-coordinated); z is the DEM which carrying the altitude values; v_0 is the spatial wind data depicted from pervious section by Kriging Interpolation; z_0 is the measured height of the MMD stations which is 10 m; α is often assigned a value of 0.143; into the power law:

$$v = v_0\left(\frac{z}{z_0}\right)^{\alpha} \tag{2}$$

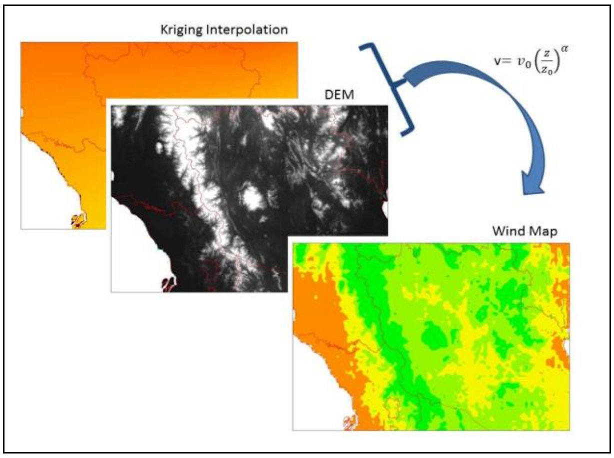


Figure 2. Spatial Wind Modeling.

DEM, Figure 3 is that the number of regional terrain, elevation Z coordinates on the plane X, Y [39]. Hence, a spatial wind data with the xyz-coordinate was extrapolated from the interpolated spatial wind data based on the DEM. The term wind map was used to describe the extrapolated spatial wind data in this section in order to differentiate interpolated (xy-coordinated) and extrapolated (xyz-coordinated) spatial wind data. DEM which carrying the altitude values was depicted by adding the value 10 m to the DEM which carrying the elevation values. The rationale of adding value 10 m to DEM was because the measured data was at 10 m height and for the purpose of depiction of a wind map to represent the spatial wind speed at the 10 m height above the ground. Besides, the extrapolation was based on 10 m MMD measured height, z_0. Therefore, it was required to add a value of 10m to the DEM to avoid the negative values obtained for the wind map.

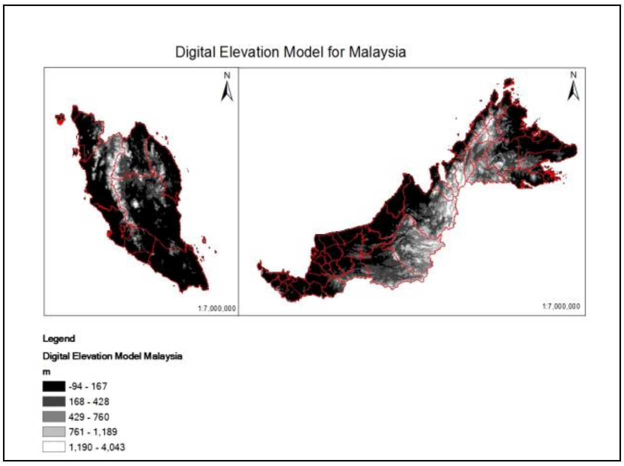


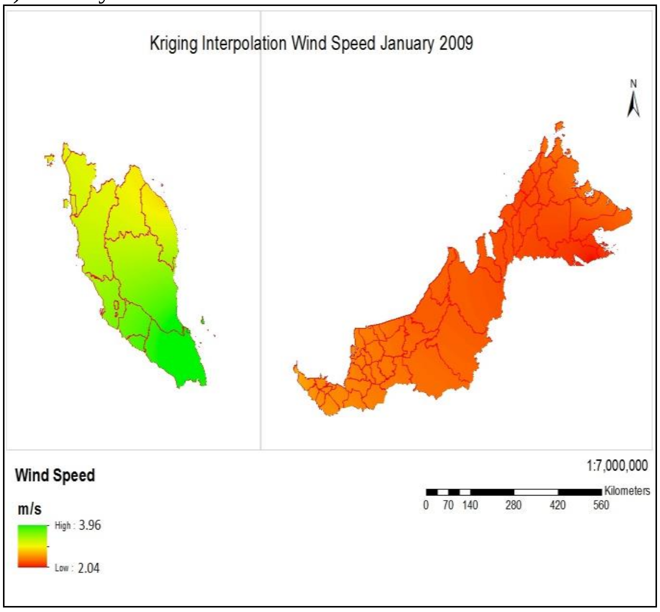
Figure 3. Digital Elevation Model for Malaysia.

3. Results and Discussion

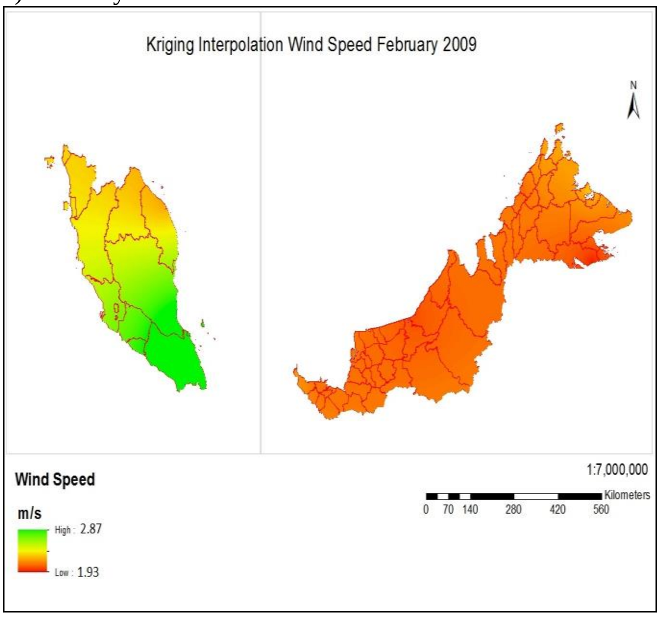
3.1. Kriging Interpolation

Figure 4 shown the spatial wind data interpolated by Kriging. The colors from red to green indicated areas that have low to high value of wind speed. Now, spatial wind data provided a visual determination of potentially high wind speed areas. Kriging interpolation uses spatial autocorrelation between sample points to explain variation in the surface [33] and predicts value at the point location that differs from its known value [30,31]. Therefore, the maximum value of mean wind speed, January as example, was not falling in the predicted range value. Kriging interpolation showed that Johor or southern part of Peninsular Malaysia was prevailed with higher wind than other areas along the year. This indicated that Johor was prevailed with wind regardless of monsoons. Besides, Figure 4 (a,c,h,k,l) show that whole Peninsular Malaysia was prevailed with stronger wind than Sabah and Sarawak during the monsoon months. In short, it was clear that the monsoons only affected the wind flow at Peninsular Malaysia. Meanwhile, Sabah, also well-known as 'The Land below the Wind', also prevailed with strong wind especially at the tip of Borneo during August to October. This was due to the seesaw pattern of atmospheric pressure between eastern and western Pacific during April to November, called *Southern Oscillation*.

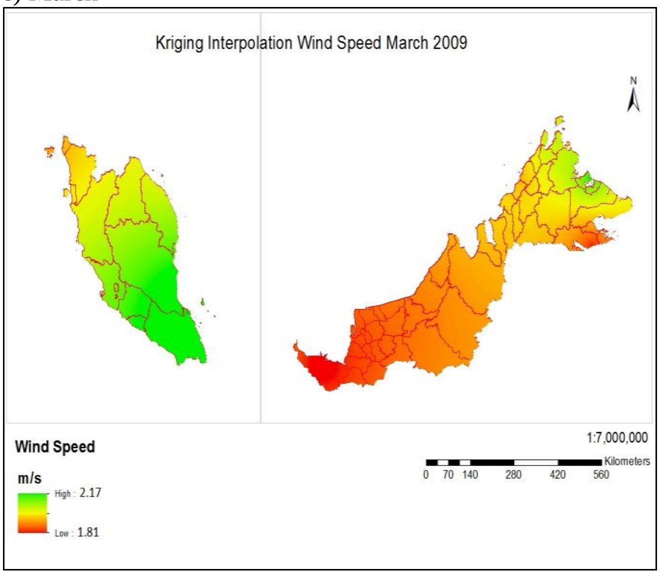
a) January



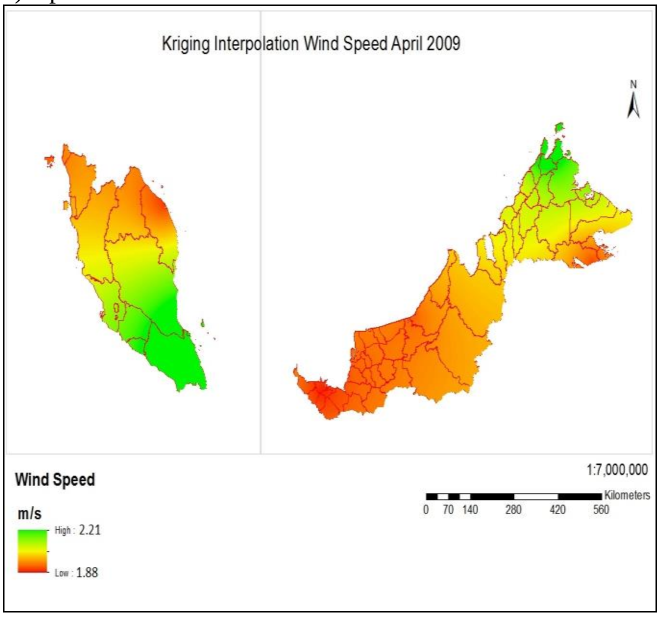
b) February



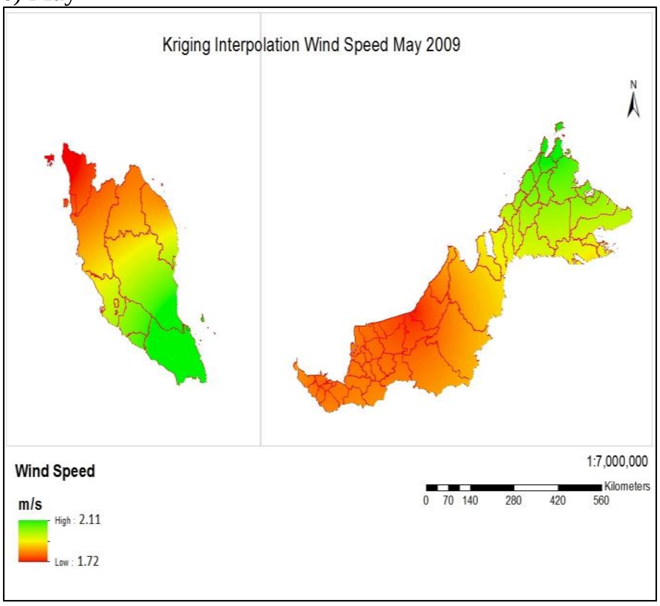
c) March



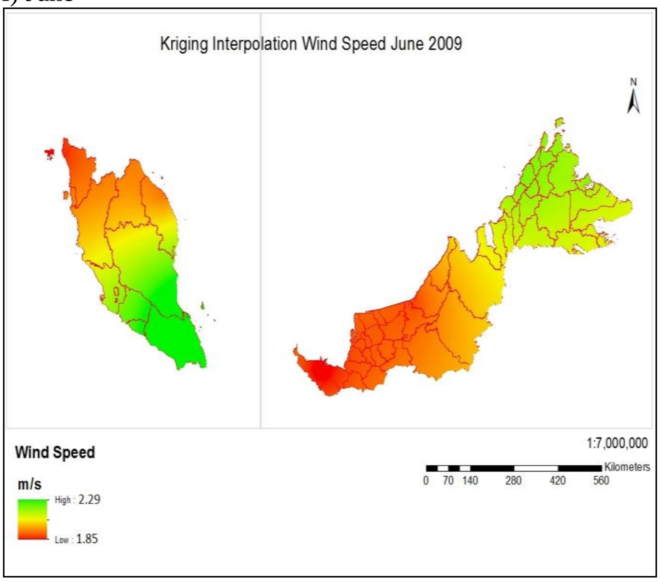
d) April



e) May



f) June



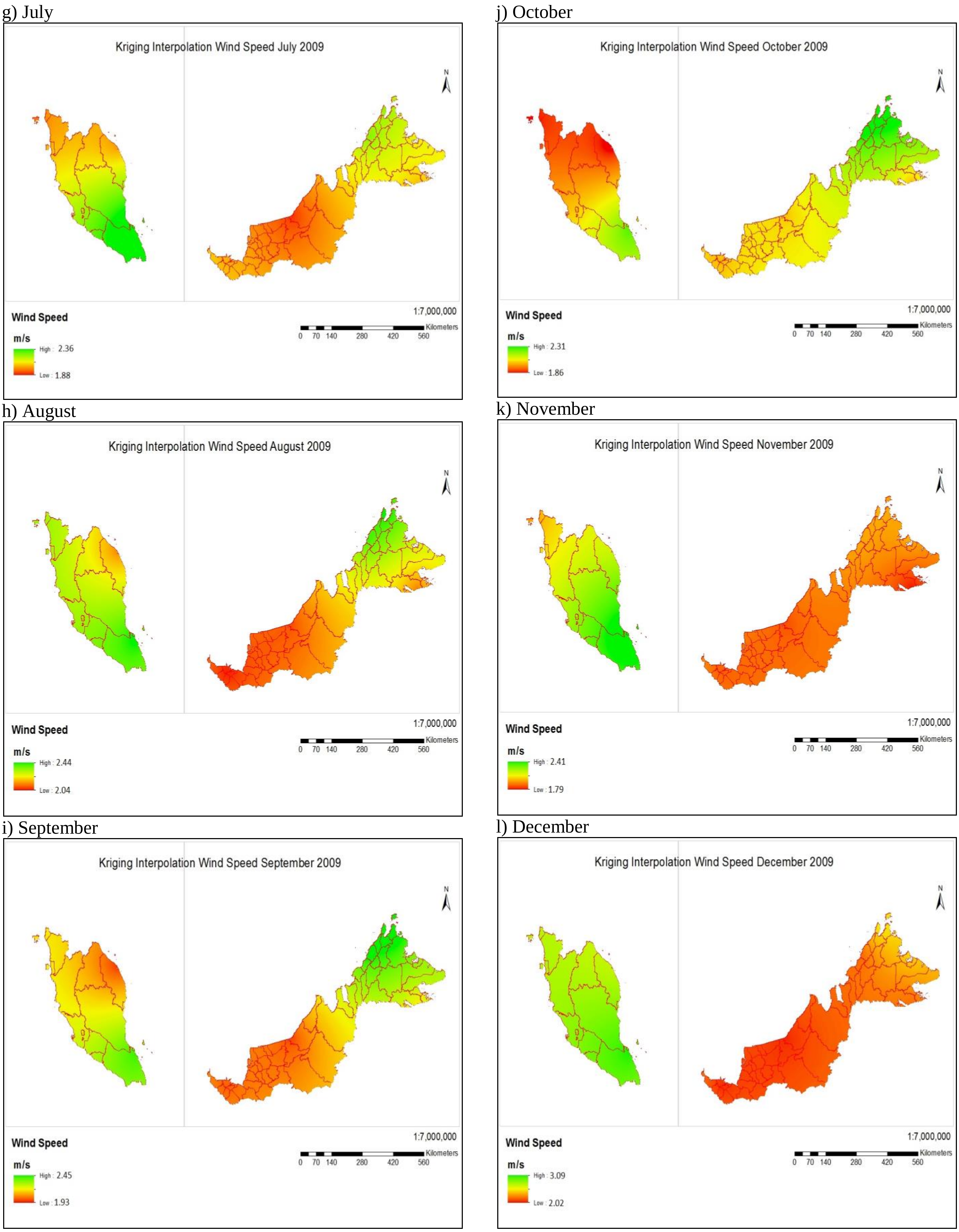
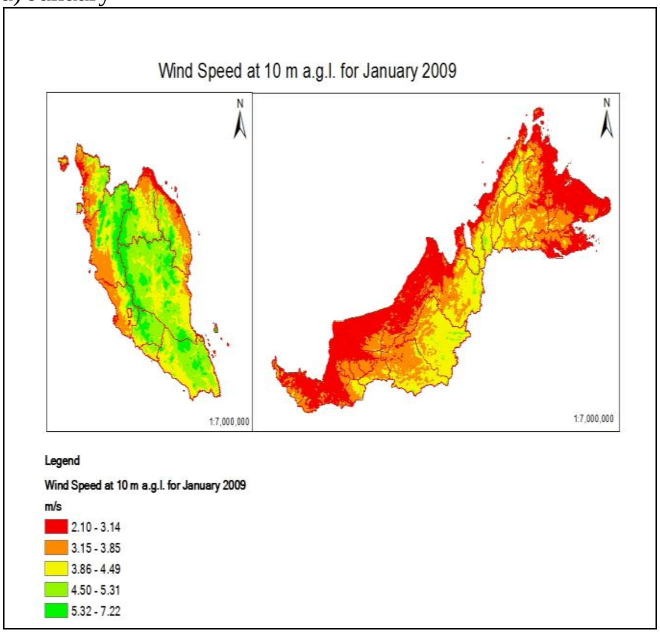


Figure 4 (a-l). Monthly Kriging Interpolation of wind speed for Malaysia.

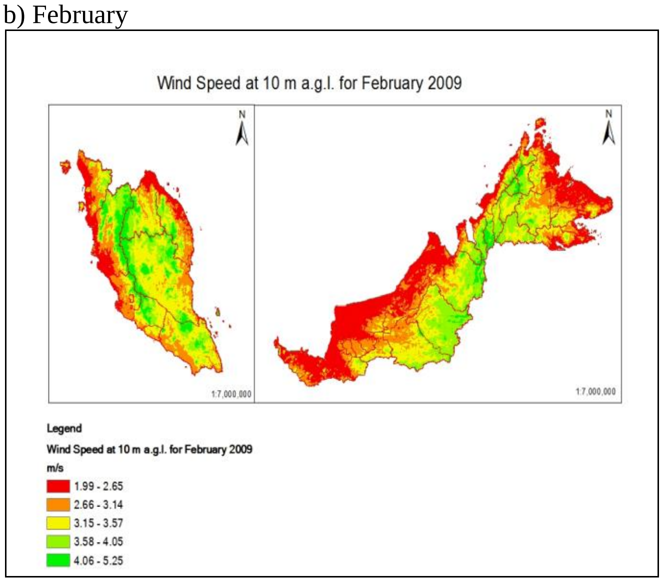
3.2. Wind Map

Hourly spatial wind data interpolated by Kriging were extrapolated to hourly wind map. Through extrapolation, the wind map could now display wind speed with its longitude, latitude and altitude (10 m height from the elevation). Then, Figure 5 shown the monthly wind map which was the mean of the hourly wind map. The colors indicator to represent the wind speed was similar as described in previous section. The color from red to green indicates wind speed from low to high. To be more precisely, the indicator was classified into five different colors which were red, orange, yellow, yellow green, and green for easier distinguishing. Figure 5 (a), (l) shows the wind maps for January and December respectively where northeast monsoon was taking place. It could be seen that the prevailing wind at Peninsular Malaysia during these period were beyond orange classes. Therefore, it could be concluded that the northeast monsoon had been affected the wind flow at Peninsular Malaysia during January and December.

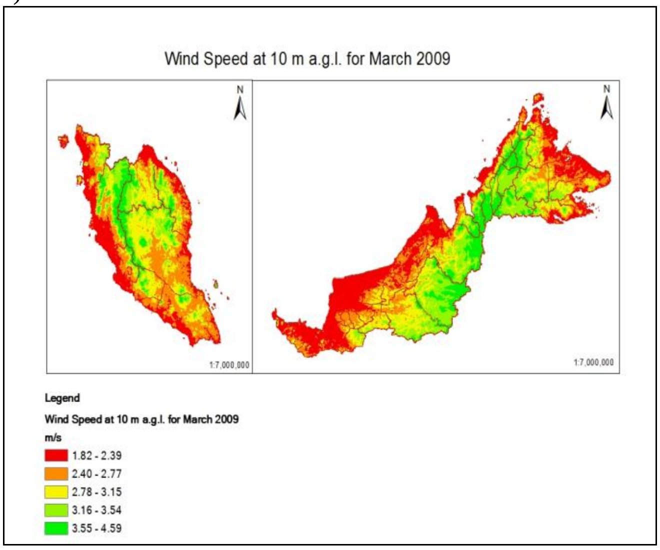
a) January



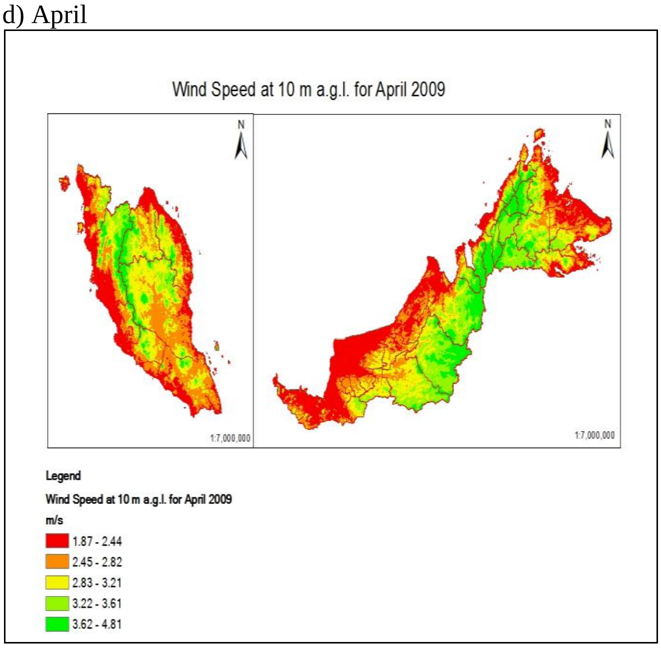
b) February



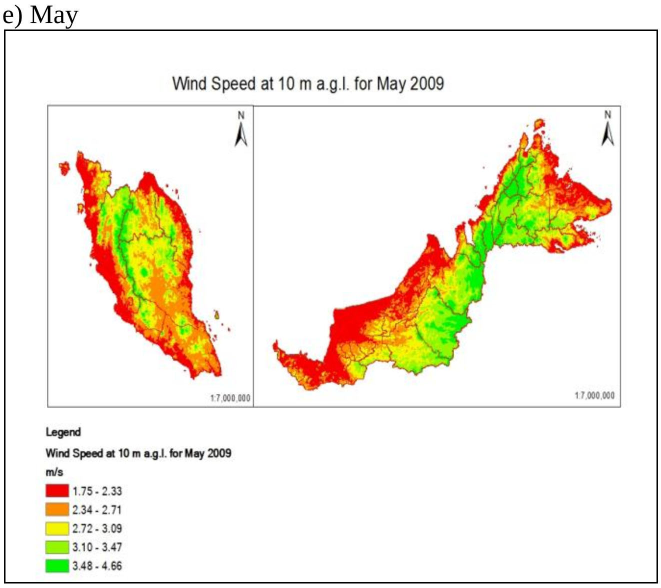
c) March



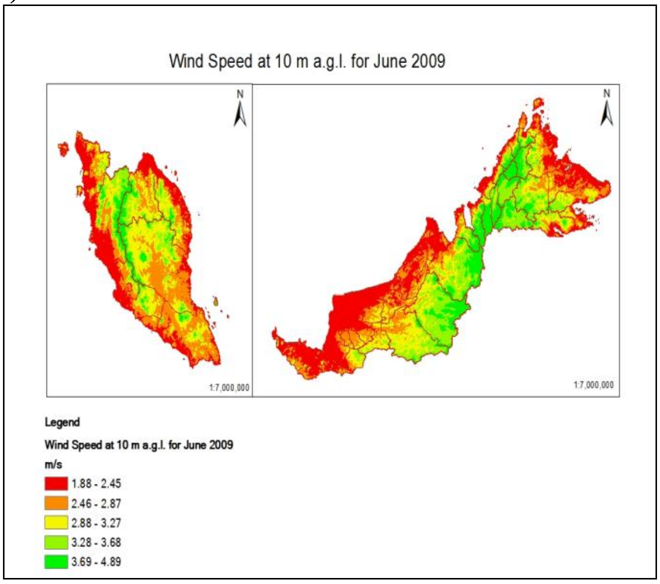
d) April



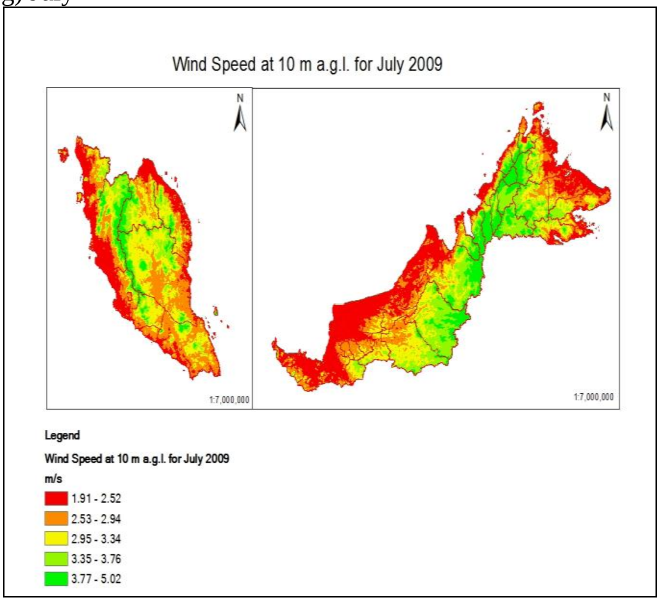
e) May



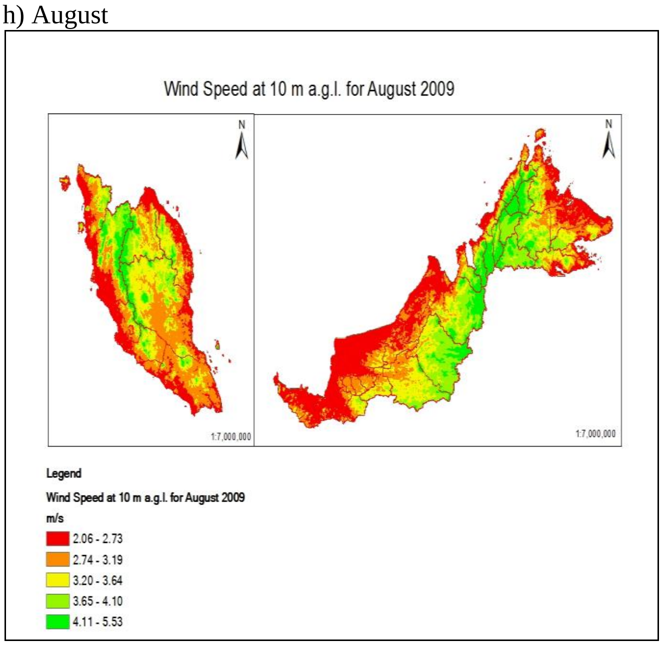
f) June



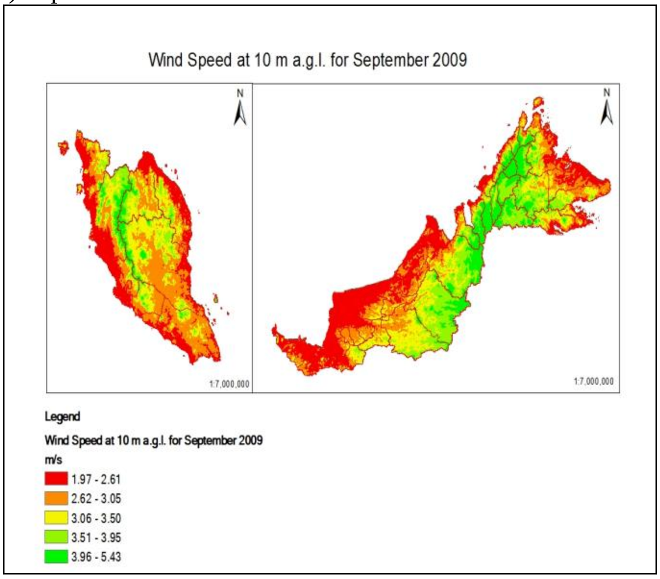
g) July



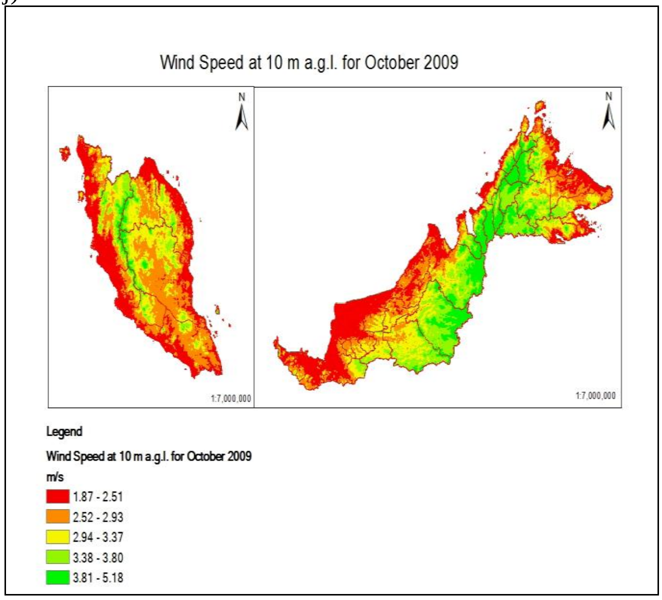
h) August



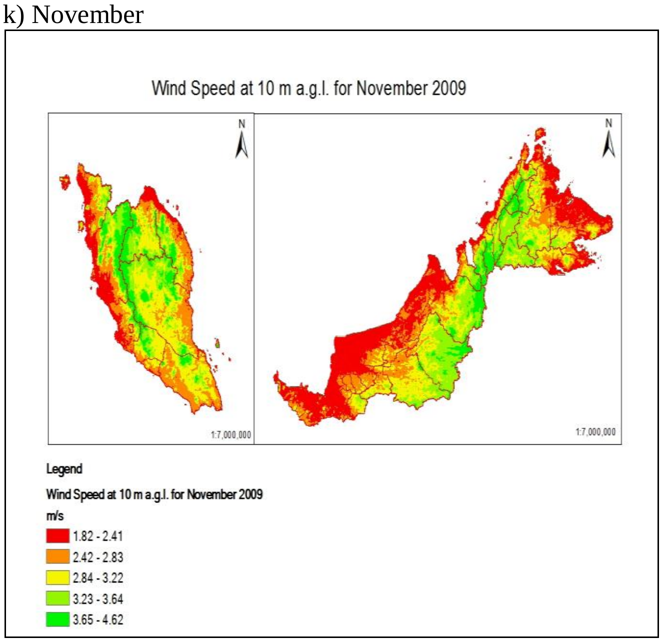
i) September



j) October



k) November



l) December

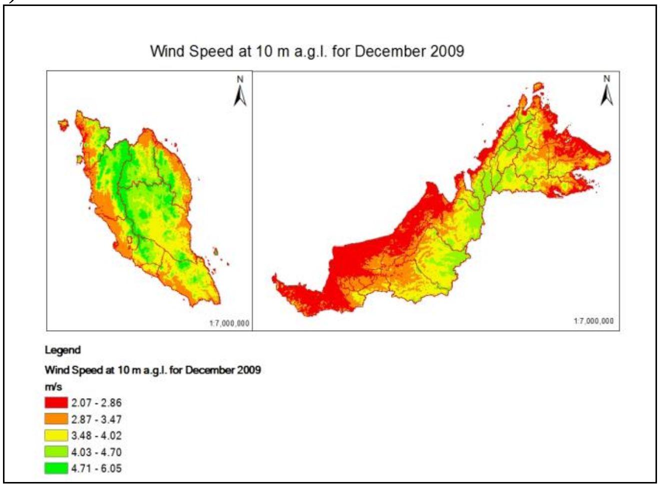


Figure 5 (a-l). Monthly 10 m height wind map for Malaysia.

The wind map also shows that mountain regional or higher altitude areas were prevailing with higher wind than other areas along the year. These results were tally with the KAMM, where higher wind speed was estimated at higher altitude [13,21]. Stronger wind prevailing at higher altitude or mountain regional was caused by the mountain-valley breeze effect. Additionally, the limitation of resolution in KAMM was no limit to the spatial wind modeling.

A segment of three dimensional (3D) views for the 10 m wind map was shown in Figure 6. The simulated wind speeds at the mountain regional were stronger which is displayed as green color. In contrast, flat areas were indicated as red color meaning low wind speeds. The simulated wind speed from January till December at mountain regional (green color) was in the range of minimum 3.48 m/s and maximum 7.22 m/s. However, the average wind speed for mountain-valley breeze could be ranged from 9 to 11 m/s [28]. Besides, the wind map also indicated that the wind speed was doubled up as the wind flow up the slope and reached the tip of a long ridge. The simulated wind speeds from January till December was ranged from minimum 1.75 m/s to maximum 3.14 m/s for flat areas; while ranging from minimum 3.48 m/s to maximum 7.22 m/s at mountain regional.

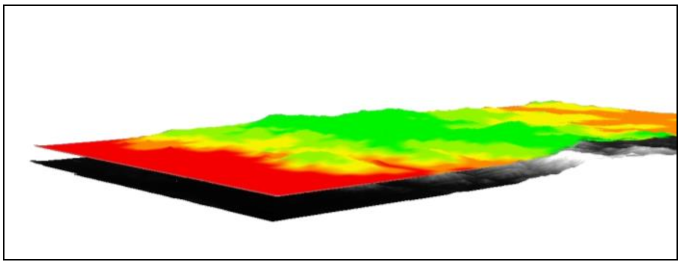


Figure 6. Segment of 3D view for the 10 m wind map.

3.3. Validation

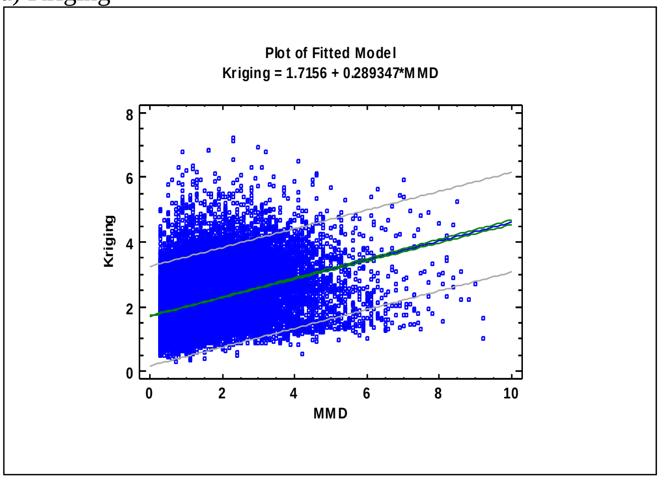
Simple linear regression between the hourly wind data measured from MMD stations and the simulated hourly spatial wind data were established to validate the spatial interpolation of wind speed throughout Malaysia. The simulated wind data for the 3 selected MMD stations, Kuantan, Cameron Highland, and Kapit were extracted from the hourly spatial wind data interpolated by Kriging methods and the hourly wind map. Validation was done in two different ways which were validation of the spatial modeling and simulation of wind speed at the different areas.

Validation of the spatial modeling was done by relating the whole year measured hourly wind data from the 3 selected MMD stations to the value extracted from the hourly spatial wind data and wind map. Figure 7. shows the regression between the MMD measured wind data and simulated wind data extracted from Kriging interpolation and the wind map respectively. For instance, the linear regression between MMD measured and Kriging wind data was:

$$\text{Kriging} = 1.7156 + 0.2893 * \text{MMD} \qquad (3)$$

Meanwhile, validation of simulation of different areas was conducted with a simple regression relating the MMD measured wind data from each station with the spatial interpolated and the wind map wind data. Kuantan was representing the flat areas; Cameron Highland was representing inland or mountain regions at Peninsular Malaysia; and Kapit was representing the inland or mountain areas at East Malaysia.

a) Kriging



b) Wind Map

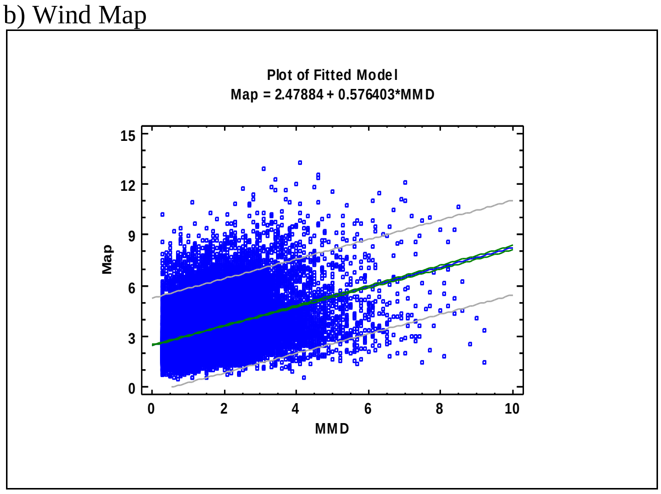


Figure 7. Regression between the whole year MMD measured wind data and a) Kriging; b) Wind Map.

The correlation coefficients for all the regression above were summarized in Table 1. The results showed that the correlation coefficient between MMD and the Kriging interpolated wind data was 0.3800, whereas MMD and the wind map simulated wind data was 0.4123. This indicated that the wind data extracted from wind map had stronger relationship with measured MMD wind data compared to the wind data extracted from Kriging interpolation. In other words, Kriging interpolation had been improved to present the spatial wind distribution in Malaysia by spatial modeling, extrapolation. The simulation for the flat areas, Kuantan, was more accurate than the mountain regions, Cameron Highland or Kapit. The correlation coefficients between the measured MMD wind data and the three types of spatial wind data (Kriging Interpolation and Wind map) was the highest in Kuantan, followed by Kapit and lastly Cameron Highland. This was due to Kuantan was near to the sampled known points compared to Kapit and Cameron Highland. The first law of spatial stated that: Everything is related to everything else, but near things are more related than distant things [30,40].

Table 1. Correlation coefficient for the regression of whole year wind data

Correlation Coefficient	Kriging	Wind Map
Spatial Modeling	0.3800	0.4123
Kuantan	0.4359	0.4359
Cameron Highland	0.3149	0.3149
Kapit	0.3953	0.3953

Another method to evaluate a model is computed its root mean square error (RMSE) with the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \tag{4}$$

where, X_{obs} is observed values and X_{model} is modeled values at time/place i. The RMSE for the Kriging interpolation and wind map were 1.1143 and 1.4949 m/s respectively. In other words, the accuracy of the Kriging interpolation and wind map were ±1.1143 and ±1.4949 m/s respectively.

3.4. Limitations and Recommendations

In this study, the limitations were divided to two parts, which were the study limitations and the spatial wind modeling limitations. Studies of the wind resources and wind energy were grouped together as one for the wind energy exploitation. However, the wind potential in Malaysia which was studied by the GIS approach only focused on the wind resources. This was due to the aim of this study was to establish a wind map that describing the spatial wind distribution in Malaysia. Besides, wind resources at the potential sites were essential for the prediction or estimation for the wind energy outcome.

Likewise, due to the purpose to establish a spatial wind distribution with lesser wind monitoring stations and the limited secondary wind data, the points of input for the spatial interpolation were set to as minimum as nine points. Certainly, a more precise spatial wind distribution was plotted by more interpolation points as the input. However, construction of a wind monitoring system was very costly. Therefore, it was more preferable to plot a spatial wind distribution that presenting the wind speed in Malaysia with lesser wind monitoring stations. Basically, a precise interpolation required more input points. However, the spatial interpolation only plotted an average wind distribution as the input for the spatial wind modeling. Then, after further extrapolation of the spatial interpolation, the wind map had been improved to present the wind distribution in Malaysia and the precision of the spatial data was now less depended on the number of spatial interpolation input points.

Moreover, wind directions were not included in this study of wind potential and spatial wind modeling. Wind direction was one of the most important factors in evaluating the characteristics of the wind regime of a particular region [24]. However, the spatial wind modeling was only concentrated on modeling variation of wind speed at different height or altitude. Besides, the wind direction was neglected as well as the effects of the surface roughness on the wind profile were not included in the spatial wind modeling.

In addition, the wind map was limited to represent wind at 10 m above the elevation. This was because the extrapolations of the wind maps were based on DEM and not Digital Surface Model (DSM). DSM contains elevations of natural terrain in addition to top of buildings, trees and any other objects [41]. If the extrapolation of the wind maps were based on DSM, it could represent the wind above the top of buildings, trees and any other objects. Besides, wind map described more precisely the winds during northeast monsoon than southwest monsoon. In other words, there were still rooms of improvement for the wind map. Nevertheless, the spatial wind modeling was suggested to include also the wind direction onto the wind regime as well as surface roughness on the variation of the wind profile. Besides, in order to describe the real world wind in a map, the extrapolation was more preferred based on DSM than DEM. Moreover, it was believed that wind map extrapolation based on DSM provided higher correlation coefficient.

Last but not least, the use of a wind map was not just limited to wind energy exploitation. A wind map could be applied in many other fields of study such as weather forecasting, climate change study, as well as air pollutant spreading model.

4. Conclusion

Kriging interpolation showed that in Johor or southern parts of Peninsular Malaysia where prevailing wind was higher than other areas along the year. From the wind maps, wind speed was presented with its longitude, latitude and altitude. Besides, the wind maps described the mountain-valley breeze effect and the wind speed was doubled up as the wind flow up the slope and reached the tip of a long ridge. As the result, mountain regional or higher altitude areas were prevailing with higher wind than other areas along the year. These were tally with the KAMM and improved the limitation of resolution on establishing wind maps for larger region. Through the validation, Kriging interpolation had been improved by wind maps to present the spatial wind distribution in Malaysia. Meanwhile, near things for instance Kuatan are more related than distant things like Kapit and Cameron Highland. Lastly, the accuracy of the Kriging interpolation and wind map were ±1.1143 and ±1.4949 m/s respectively. As a suggestion, a wind map could be applied in many other fields of study such as weather forecasting, climate change study, as well as air pollutant spreading model.

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