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LOCAL CONDITIONS WIND MULTIPLIER MAP AS SUPPORTINGTOOL IN WINDSTORM HAZARD ASSESSMENT FOR MALAYSIAN DISTRICTS (STUDY CASE: KUANTAN, PAHANG)

Mohd Fairuz Bachok[1], Khairi Khalid[1], Supiah Shamsudin[2], Roslan Zainal Abidin[3], Ponselvi Jeevaragagam[4] and Sobri Harun[4]
[1]Faculty of Civil Engineering, Universiti Teknologi MARA Cawangan Pahang, Pahang, Malaysia
[2]FDL Facile Global, Kuala Lumpur, Malaysia
[3]School of Engineering and Technology Infrastructure, Infrastructure University Kuala Lumpur, Selangor, Malaysia
[4]Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia
E-Mail: fairuzbachok@gmail.com

ABSTRACT

Local conditions wind multiplier map considered as one of the essential supporting tool in windstorm disaster management because throughthis map effected of local conditions to windstorm intensity (gust/wind speed)in anygrid area of 1 km x 1 km can be made known. Local conditions multiplier for each grid area need to be multiplied with predicted windstorm intensity from the source (downdraft) in order to determine the actual intensity on land surface. Next, through the actual intensity, potential damages can be identified. Information regarding potential damages enables local authorities and public in the affected area to make early preparation in minimizing the impacts caused by windstorm occurrence. Production of this map is according to severe wind gust risk assessment which taking into account of terrain (roughness), shielding multiplier and topographic (hill-shape) factors. Multiplier for each factor are based on the Malaysian Standard (MS1553: 2000) and Australian/New Zealand standard (AS/NZS1170.2: 2011). Kuantan District has been selected as a case study based on two factors, one of a district in Malaysia with highest number of windstorm occurrences and the only district that has been studied about its land cover roughness. As a matter of fact, this article is to provide guidance in producing supporting tool that could be as added value in windstorm disaster management in the future.

Keywords: hazard assessment, local conditions, map, Malaysian districts, wind multiplier.

1. INTRODUCTION

Windstorm producing-thunderstorms are capable to cause enormous of damages. Damages by the windstorm are to the building, properties and tree. This can be seen in the list of destructions of several classification schemes that related with the windstorm such as Beaufort, Fujita and TORRO Scale. Characteristics of the windstorm which contain the leading edges (gust front) have significant wind speeds and a strong wind shear. The action of the wind is caused by its force effects on objects, when exceeding the limits of their strength or resilience, material damage will be produced. The spectrum of damage is very broad. The wind will lose their strength on the landfall primarily due to the frictional resistance of the ground surface, resulting in a rapid decrease in wind speeds. Damages of the windstorm could extend to the secondary damage such as wind transported (roof cover) or fallen tree that could destroyed property, cause injury and claim life to the human. Strong winds could be uprooted trees, blew off roofs, toppled over lamp posts and cause chaos and this event frequently occurs when a cluster of thunderstorms affects an area for a prolonged period of time [1].

Thunderstorm is known as global and localized phenomena. It can occur anywhere in the world, form and develop in any particular geographic location and at any time. Thunderstorms are responsible for the development and formation of many severe weather phenomena. In Malaysia, thunderstorms occur throughout the year but are most likely to occur in the inter-monsoon periods. Unlike in cyclone prone region, the thunderstorms occur in micro scale and short-lived which between 15 to 30 minutes [2]. Strong wind which one of the severe storm by-product is related to the development of thunderstorm clouds (severe convective storm, multi-cell storm, super cell storm), short duration (usually dozens of minutes) and the locally limited damage.

On land, wind speeds will be affected by surface roughness whereby the wind flow may accelerate or decelerate depending to the changes of surface roughness which the rougher the terrain is, the more it retards the wind speed [3]. Besides local roughness factors effected wind speed magnitudes, another factors are shielding and topographic factors. Wind speed needs to be factored by considering local environment, so that quantitative specific velocity for a particular site can be estimated.

Topography, geographic terrain and surface roughness factors should be considered as multipliers severe wind gust risk assessment [4 - 7]. Besides, land use should be the feature of the Atmospheric Mesoscale Model on extreme wind of winter storms [8]. Without considering the effects of local conditions that will cause the measurement of wind speeds to be inaccurate either under- or over-rated. Therefore, local conditions wind multiplier map should be produced so that the actual value of downdraft wind speed can be made known when it reached on land surface. The actual wind speed on land surface is an indication to potential damages that could be caused by a downdraft. Thus, by knowing the wind speed release during the downdraft (refers to gust speed or windstorm intensity) on land surface, indirectly the potential damages can be identified. Moreover, extreme losses during severe windstorm events could be prevented since buildings resistance in specific zones is constructed through highlight impacts of windstorms and emphasis evidence of increasing losses under both future climatic and demographic conditions [9].

The production of a scale that correlates between the intensity of the windstorm and its potential damages will be a huge advantage because the information on this scale will not only depict the possible damages experienced by the public when a windstorm occurred, but also, they will know whether or not they are in a safe surrounding. Effective early warning is a system which not only issue a timely warning and possible hazards that will be occurred at the suggested time but location and with the intensity as well [10].

2. PRODUCTION OF LOCAL CONDITIONS WIND MULTIPLIER MAP

Kuantan district is a state capital of Pahang, one of the states in Malaysia, situated at East Coast region in Peninsular Malaysia with area approximately 2960 km^2. Kuantan is selected as study district because it has the highest number of windstorm occurrences and the only district which study been carried out with subjected to its land cover roughness [11].

Production of local conditions wind multiplier map is the same as severe wind gust risk assessment [6]. Wind risk assessment methodology for severe wind gust actually intended to assess the risk that severe wind gust poses to major communities. Therefore, heuristically vulnerability models can be derived for appropriate construction type. It is based on the following equation:

$$V_{site} = V \times M_d \times M_z \times M_s \times M_t \quad (1)$$

where

V_{site} = maximum local (site) wind speed
V = wind speed
M_d = directional multiplier
M_z = terrain (roughness) multiplier
M_s = shielding multiplier
M_t = topographic (hill-shape) multiplier

However, it is modified without taking into account the directional multiplier parameter (M_d). Once modified, the equation was converted to the following equation:

$$V_{site} = V \times M_z \times M_s \times M_t \quad (2)$$

Where

V_{site} = maximum local (site) wind speed
V = wind speed
M_z = terrain (roughness) multiplier
M_s = shielding multiplier
M_t = topographic (hill-shape) multiplier

M_d is not being considered since this parameter is related to the assessment of global wind direction which heading to the area for number of years in order to determine the multiplier of wind directional of that particular area. However, in the case of windstorm-producing thunderstorms, when a gust touches the land surface, the gust direction can possibility spreading out heading towards all directions or directions which does not follow the direction of global wind during that particular time [12]. This indicated that M_d have no relation with the local conditions of the land surface.

Basic maps that were needed to produce local conditions wind multiplier map are:

a) Land use map from Department of Agriculture Malaysia
b) Topographic map from Department of Survey and Mapping Malaysia

Both basic maps need to be modified by digitizing or layering before hand to get the value of local conditions multiplier, M_z, M_s and M_t through either Malaysian standard (MS1553:2000) in Table-4.1 or Australian/New Zealand standard (AS/NZS1170.2:2011) in Table-3.5 and Table-3.6.

The production of these new maps whether digitizing or layering on the basic maps are by using GIS ArcGIS software. First, district digital map need to be opened in ArcGIS to identify boundary of Kuantan district (Figure-1). Then, topographic map is produced by opening the digital topographic map in ArcGIS and then labelling each elevation difference (Figure-2). Next, terrain map is produced by digitizing land use map into 4 different terrain classes namely class 1, class 2, class 3 and class 4 (Figure- 3).

Classifying land use is according to terrain class in accordance with the list of classes by Australian/New Zealand standard. Terrain (roughness) map is produced by layering terrain map with the topographic map (Figure-4). While, shielding map is produced through digitized land use map and based on the list of terrain classes by Australian/New Zealand standard but only involves 4 terrain classes namely city buildings, high density metro, suburban/centre of small towns and others (Figure-5). Lastly, the topographic (hill-shape) map is produced by modifying the topographic map through Arc Toolbox process > Data Management Tools > Features > Feature to Polygon into several categories of hill slopes (in degrees) as listed by Australian/New Zealand standard (Figure-6).

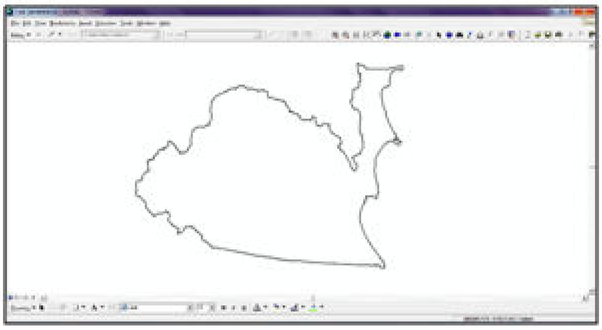

Figure-1. District map of Kuantan.

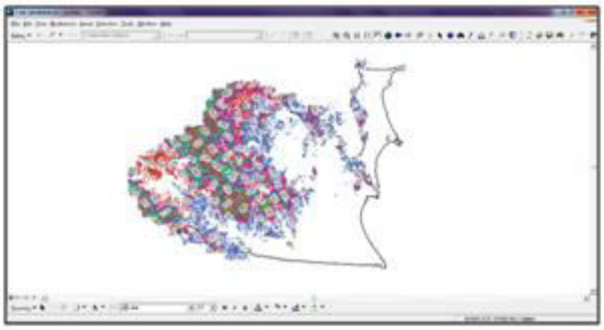

Figure-2. Topographic map of Kuantan.

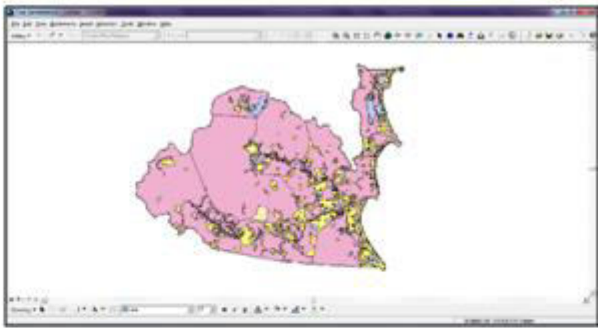

Figure-3. Terrain map of Kuantan.

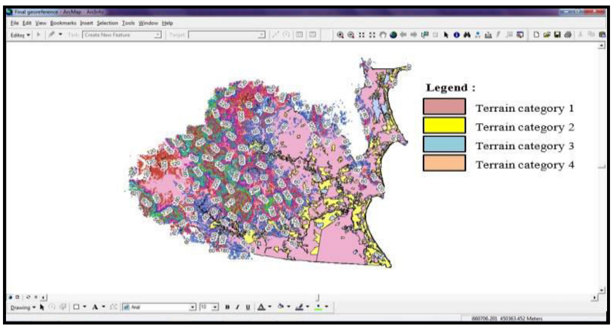

Figure-4. Terrain (roughness) map of Kuantan.

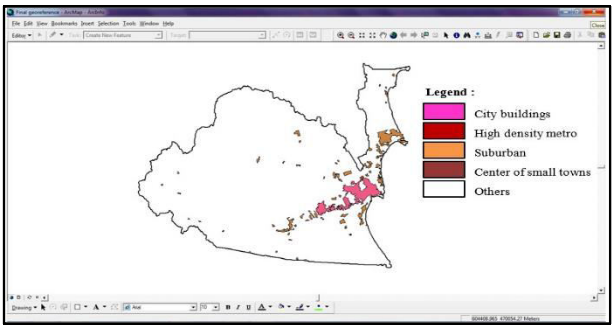

Figure-5. Shielding map of Kuantan.

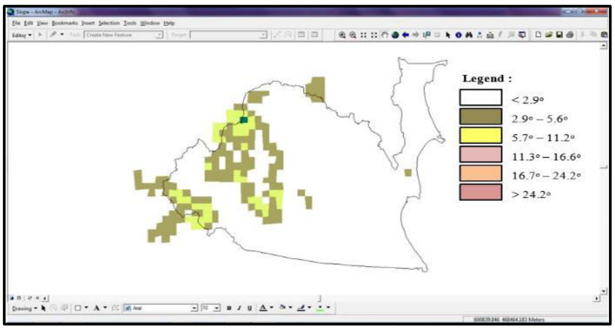

Figure-6. Topographic (hill-shape) map of Kuantan.

3. RESULT AND DISCUSSIONS

This map was produced to ensure the intensity of the strong wind on the land surface from windstorm-producing thunderstorms could be estimated more accurately, which it does not depend solely on the gust speed that been recorded by the meteorological station but also considering local conditions factor. On the other hand, the gust speed recorded need to be multiplied by local conditions multiplier in order to determine the actual gust speed on the land surface. Beside the thunderstorm cell distance from the center, other major factors affected the wind profiles during thunderstorms are intensity of the storm and the ground roughness [5].

For example, if the wind multiplier at the area of meteorological station, $M_{o\_meteorigalstation}$ is 1.33, while the other area underneath convective cluster, $M_{o\_damages}$ is 0.91 and the highest observations gust speed recorded by meteorological station, $V_{maximum}$ is 9.0 m/s. Thus, the intensity on land surface for that particular area is:

$$V_{site} = V \times M_z \times M_s \times M_t \text{ or}$$

$$V_{meteorigalstation} = V_{maximum} \times M_{o\_meteorigalstation}$$
$$= 9.0 \text{ x } 1.33 = 11.97 \text{ m/s}$$

$$V_{damage} = V_{meteorigalstation} \times M_{o\_damages}$$
$$= 11.97 \text{ x } 0.91 = 10.9 \text{ m/s} = 39.3 \text{ km/h}$$

Therefore, each area with different local conditions underneath convective cluster that produce strong downdraft, the actual gust intensity from strong wind in the particular area could be determined. Differences of local conditions on the land surface should be considered because the land surface affecting the gust

ARPN Journal of Engineering and Applied Sciences

speeds, whether it will be accelerating or decelerating the gust speed, even though in fact it is originally release from the same convective cluster.

Topographic and landuse maps are the two basic maps that need to be digitized, modified and layered together to produce local conditions wind multiplier map. The purpose is to determine local conditions multiplier for all the area through the map and either Malaysia or Australian/New Zealand standard. Grid 1 km x 1 km also been embedded in Google Earth in order each area or specifically grid area will have its own multiplier local conditions (Figure-7). Figure-8 shows that local conditions wind multiplier map embedded in Google Earth. Its aims to ensure that the map is much easier to use by the public (user friendly) as people are more familiar using Google Earth map compared with ArcGIS which more complicated in technical aspects.

Since there are some classified landuse in Kuantan landuse map were not in the list of terrain classes by Australian/New Zealand standard, so to overcome the lack of these information, [13] is being referred as a guideline. For example, recreational area terrain is one of the landuse which is not in the list of terrain classes. Thus, by referring to Roughness Length, Zo parameter for the golf course that been estimated [13], then compared with Zo [14], the terrain class can be classified. In this case, recreational area is classified as a terrain class 3.

Local conditions multiplier would provide a clearer picture on the potential damages in area since the actual intensity (maximum intensity) of windstorm-producing thunderstorms or worst scenario in that particular area can be estimated. Thus, local authorities and public can make an early preparation to minimize the impacts.

Table-1shows another factor that made local conditions wind multiplier map is essential supporting tool which should to be part of windstorm disaster management. Through lowest and highest local condition multipliers indicated that local conditions significantly affect the intensity because not only can increase up to twice higher intensity on land surface, but also can reduce its nearly doubled. If effect of local conditions is not being considered, area where effect of local conditions could increase the intensity, despite warning, there is high possibility that early preparations may not taking into account the increase of the intensity, consequently the impacts of occurrence will not be entirely minimized. While, area where effect of local conditions could decrease the intensity, sometimes its will lead to no damages produced, this actually causes wastage on warning and early preparation.

Through comparison between intensity associated with damages which taking account of local conditions multiplier in Table-2, its justified that this approach applied in producing the local conditions wind multiplier map is applicable and also well suited for being use in this country. This is due to all intensity associated with damages as shown in Table-2 were below of intensity that causes structure collapsed of high-rise building. Structure collapsed of high-rise building in Penang on year 2013 is caused by estimation wind speed equal to 17.46 m/s [15]. As a fact, higher intensity is acquired to cause damages to engineered building than non-engineered building. Intensity associated damages in Table-2 were estimated through several windstorm occurrences in Kuantan district where its damages and meteorological station were underneath the same convective cluster that produced windstorm.

1	588	589	590	591	592	593	594	595	596	597	598	599	600	601
613	0.85	0.99	0.75	0.75	0.75	0.75	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
614	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.81	0.73	0.73	0.73	0.73	0.73	0.73
615	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.81	0.73	0.73	0.73	0.73	0.73	0.73
616	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.81	0.73	0.73	0.73	0.73	0.73	0.73
617	0.75	0.75	0.75	0.75	0.99	0.99	0.99	0.99	0.99	0.73	0.73	0.73	0.73	0.73
618	0.99	0.75	0.75	0.99	0.99	0.99	0.99	0.99	0.99	0.73	0.73	0.73	0.73	0.73
619	0.99	0.75	0.99	0.99	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.99	0.85
620	0.75	0.99	0.99	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.99	0.85
621	0.75	0.99	0.99	0.81	0.81	0.81	0.81	0.81	0.81	0.75	0.75	0.75	0.75	0.85
622	0.75	0.73	0.73	0.73	0.73	0.73	0.73	0.81	0.81	0.99	0.75	0.75	0.75	0.85
623	0.84	0.73	0.73	0.73	0.73	0.73	0.73	0.81	0.81	0.84	0.84	0.84	0.75	0.99
624	0.84	0.73	0.73	0.73	0.73	0.73	0.73	0.81	0.81	0.84	0.84	0.84	0.84	0.84
625	0.84	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.84	0.84	0.84	0.84	0.84
626	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.85	0.85	0.85	0.84	0.84	0.84

1	602	603	604	605	606	607	608	609	610	611	612	613	614	615
613	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.69	0.69	0.69	0.69	0.99
614	0.73	0.73	0.73	0.73	0.69	0.69	0.99	0.99	0.99	0.69	0.69	0.69	0.69	0.99
615	0.73	0.73	0.73	0.73	0.69	0.69	0.85	0.85	0.85	0.85	0.85	0.69	0.69	0.99
616	0.73	0.73	0.73	0.73	0.69	0.69	0.85	0.85	0.85	0.85	0.85	0.69	0.69	0.99
617	0.81	0.81	0.69	0.69	0.69	0.99	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.99
618	0.81	0.81	0.69	0.69	0.69	0.99	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.99
619	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.99	0.99
620	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.99	0.99
621	0.85	0.85	0.85	0.85	0.85	0.85	0.99	0.99	0.99	0.99	0.99	0.99	0.99	
622	0.85	0.85	0.85	0.85	0.85	0.85	0.99	0.99	0.99	0.99	0.99	0.99	0.99	
623	0.85	0.85	0.85	0.85	0.85	0.85	0.99	0.99	0.99	0.99	0.99	0.99	0.99	
624	0.84	0.85	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	
625	0.84	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99			
626	0.75	0.75	0.75	0.75	0.75	0.99	0.99	0.99	0.99	0.99				

Figure-7. Typical local conditions multiplier for each grid area of 1 km x 1 km.

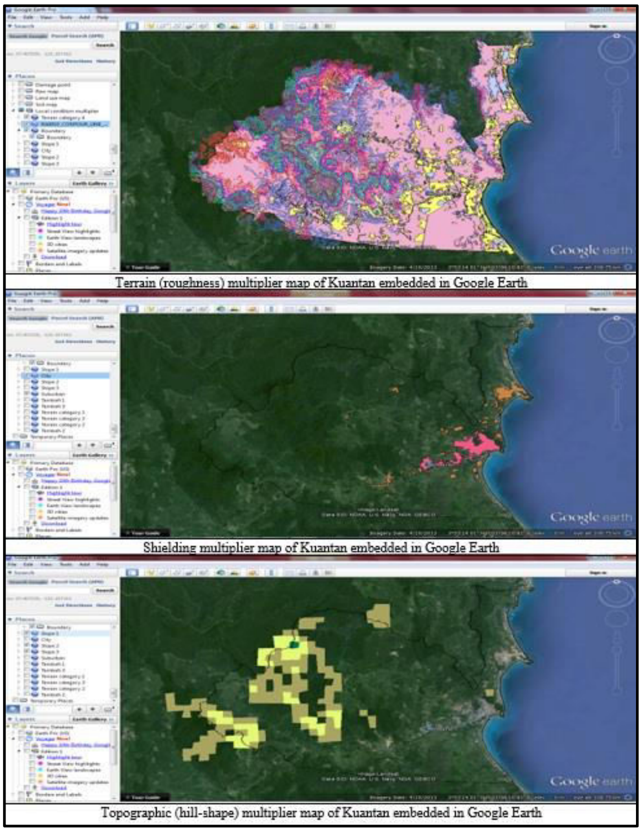

Figure-8. Local conditions wind multiplier map of Kuantan embedded in Google earth.

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ARPN Journal of Engineering and Applied Sciences

Table-1. Local conditions multiplier range for each range height.

Height (m)	Local conditions multiplier
≤ 3	0.64 - 1.69
3 – 5	0.64 - 1.80
5 – 10	0.64 - 1.92
10 – 15	0.64 - 1.98
15 – 20	0.64 - 2.03
20 – 30	0.68 - 2.09
30 – 40	0.72 - 2.12
40 – 50	0.77 - 2.14
50 – 75	0.83 - 2.17
75 – 100	0.88 - 2.21
100 – 150	0.94 - 2.24
150 – 200	0.99 - 2.26
200 – 250	1.02 - 2.29
250 – 300	1.05 - 2.31
300 – 400	1.09 - 2.34

Table-2. Sample of intensity associated with damages for windstorm occurrences in Kuantan.

Damages	**Intensity (maximum gust speed) recorded by meteorological station**(m/s)	**Intensity (gust speed) with taking account of local conditions multiplier**(m/s)
Damages roof truss (wood): non-engineered house	16.5	12.0
Loss of roof covering material (asbestos): non-engineered house	16.5	12.0
Loss of roof covering material (asbestos) :non-engineered house	15.0	15.2
Loss of roof covering material (asbestos) :non-engineered house	16.5	12.0
Loss of roof covering material (zinc):non-engineered house	15.0	15.2
Loss of roof covering material (zinc) :non-engineered house	15.0	13.7
Loss of roof covering material (zinc):non-engineered house	16.5	12.0

4. CONCLUSIONS

Production of local conditions wind multiplier map is an added value to the windstorm disaster management in the country. This due to fact that the map is an essential supporting tool in establishment of classification scheme (magnitudes scale or damages scale) which classified between intensity of the windstorm with its potential damage and part of information sources inwindstorm early warning system. Through the map, each grid area of 1 km x 1 km will have its own local conditions multiplier, therefore any damages that caused by windstorm at particular grid area, its actual intensity can be estimated more precise due to estimation of intensity had taking into account effect of local conditions. Thus, magnitude scale can always be updated since any intensity associated with damages can be determined precisely. Magnitude scale need to be continuously adding and extending new damages due to there is possibility of some damages may not be found that match the ones available today. Potential damages identified through magnitude scale will be included as part of disseminated early warning information to the affected areas, so that local authorities and public could planned early preparation in order to minimise the impacts of windstorm occurrence. Therefore, as a result, this map should be developed for each district in Malaysia since not only due to high frequency of windstorm occurrences in the country, but also damages by a windstorm causes various adverse impacts to humans, properties and economy.

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