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Reconstruction of rainfall region boundaries for the western region found by Dale (1959) in Peninsular Malaysia

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Abstract: Re-delimitation of rainfall regions plays an important role in determining the rainfall pattern of an area. This study aims to reconstruct the delimitation of rainfall regions for the western region of Peninsular Malaysia. This study involved only the collection of rainfall data at 133 stations from 1960 to 2010. These data were obtained from the Department of Irrigation and Drainage, Malaysia. The analysis methods applied include kriging, contouring and topology using a geographical information system. The results showed that the new delimitation of the western region has been formed with an area reduction of 10% compared to the original western region found by Dale. This is due to some areas in the western region have not received rainfall between 2540 and 2794 mm. The area that getting the rainfall between 2540 and 2794 mm is 46,413.6 km^2, in contrast to the sized of Dale's western region of 51,596.2 km^2. The area that frequently getting rainfall of between 2540 and 2794 during 1960s to 2010 are Parit Buntar, Taiping, Kuala Kangsar, Ipoh, Teluk Intan, Tanjong Malim, Batang Kali, Cameron Highlands, Subang, Petaling Jaya, Klang, Kajang and Bangi. The new delimitation formed through this study can be used as a guide by the agencies that manage water resources in Perak, Selangor and Negeri Sembilan in planning a more efficient water supply system.

Keywords: GIS, isohyetal method, Peninsular Malaysia, rainfall region boundaries

INTRODUCTION

Rain is one of the liquid forms of precipitation, where the diameter of a raindrop is more than 0.5 mm [Wan Ruslan 1994]. According to Islam *et al.* [2012], rain is an important part of the hydrological cycle, and a change in its pattern can directly affect water sources. Every area has different rainfall and rainfall frequency, due to several factors such as location, topography, monsoon season, land use changes and global climate change. According to Tanggang *et al.* [2004], the monthly and annual rainfall received throughout Malaysia is highly influenced by the monsoon season, or monsoon rain.

Several studies have been conducted in Peninsular Malaysia in relation to various aspects of rain. However, these studies were done in general. According to Ab. Latif [1994], in the studies on rainfall patterns in Peninsular Malaysia by Dale [1959] and Chia [1974], a boundary to distinguish the western part of Peninsular Malaysia as its own rainfall area has been created, but analyses on rainfall characteristics are limited because the results of the studies only provide a general overview of the changesin rainfall pattern through space and time. Lockwood [1967] and Lim [1976] have also conducted a study on the changes of seasonal rainfall for all of Peninsular Malaysia without focusing on any specific area. Meanwhile, more recent studies, such as those by Chan [1985; 1990; 1991] and Ab. Latif [1994], have analysed the rainfall and drought patterns only by considering the northwestern part of Peninsular Malaysia to be an area of its own.

Thus, analysing the various aspects of rainfall is important, especially in examining rainfall distribution patterns in more detail. Information on the changes in the rainfall distribution in an area is very important and useful for water resource planning, detecting droughts and floods and economic activities, and it can be used as a guide in other planning strategies related to water sources. The methodology used are kriging interpolation and contouring techniques using a Geographic Information System (GIS). The existing region boundaries as defined by DALE [1959] are no longer relevant, because they are influenced by space and time. Therefore, this study will reconstruct new boundaries of the rainfall region for the western region of Peninsular Malaysia based on rainfall trends and intensities.

Based on DALE's [1959] study, Peninsular Malaysia has been divided into five rainfall regions, namely the Northwest, West, East, Southwest and Port Dickson-Muar Coast (Fig. 1). The Northwest receives less than 2540 mm of rainfall; the West receives >2540 mm, the East receives >2794 mm and Port Dickson-Muar Coast receives 2032–2540 mm. Meanwhile, the Southwest is considered a dry area that receives less than 2286 mm of rain a year. This region is considered a dry area because it does not receive a high amount of rainfall. These regions have been used as a guide by the Malaysian Meteorological Department and the Department of Irrigation and Drainage in categorizing rain areas and in planning the use of water resources for irrigation and other domestic purposes. The isohyetal method was used in the construction of the boundaries of this rainfall region (Fig. 1), as well as the rainfall data from the rain stations available during these years (21 stations), to describe the rain areas in Peninsular Malaysia. In 1959, the data were suitable and could describe the condition of rain areas in Peninsular Malaysia. However, the increase in the number of meteorological stations throughout Peninsular Malaysia today definitely results in an increase in the amount of meteorological data observed.

STUDY MATERIALS AND METHODS

The study area was focused on the western region of Peninsular Malaysia, based on the division of territory that has been determined by DALE [1959]. The western region was selected as a study area because of the problem of a lack of water supply that often occurs in this region. However, according to Dale, the western region receives more than 2540 mm of rain a year, a high amount of rainfall. The classification of rainfall regions developed by Dale in 1959 should be re-examined, as this scenario is no longer accurate and is not being reflected in reality as stated in Dale's study. Therefore, this study needs to be conducted to re-confirm the rainfall characteristics of the western region. A total of 133 rain stations were involved in this study (Fig. 2).

This study involves the collection of secondary data, namely rainfall data from 1960 to 2010 obtained from the Department of Irrigation and Drainage, Malaysia. The boundaries of the rainfall regions were constructed using the isohyetal method, which is a method used to differentiate the distribution of rain spatially in certain areas [ANAND, KARUNANIDHI 2020]. The analysis techniques used are kriging interpolation and contouring techniques using a Geographic Information System (GIS). A GIS is a computer system that collects, maintains, stores, analyses, publishes and disseminates spatial data and information [AL-TIMIMI *et al.* 2020]. Nowadays, the concept of a GIS has been widely used in many fields, especially the field of hydro-climatology. A GIS is the best tool to analyse spatial data [BARI, VENNILA 2020; GOOVAERTS 2000; LI *et al.* 2010]. Among the researchers who applied GIS to look at rainfall distribution or spatial patterns are PRAVEEN *et al.* [2020], BARI and VENNILA [2020] and KAIWART *et al.* [2020].

Contouring is a process in which the formation of contour lines is made based on raster data, such as kriging interpolation, by considering the same values in an area based on the principle of line construction in isohyet. Contours are lines that connect points of equal value (such as altitude, temperature, rainfall,

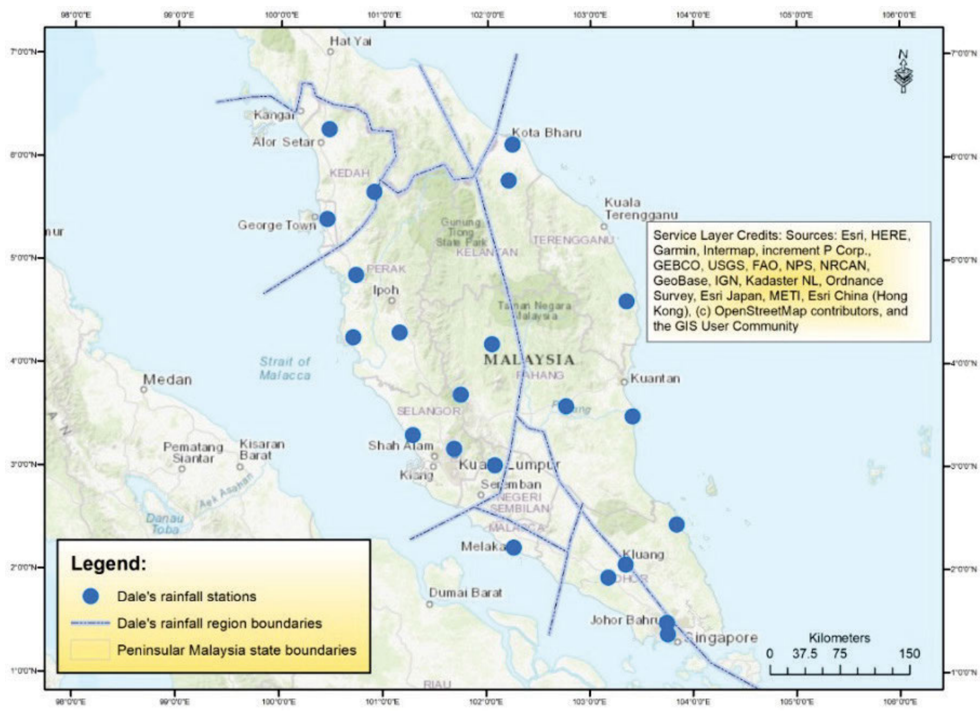

Fig. 1. The rainfall regions in Peninsular Malaysia according to DALE [1959]; source: own elaboration

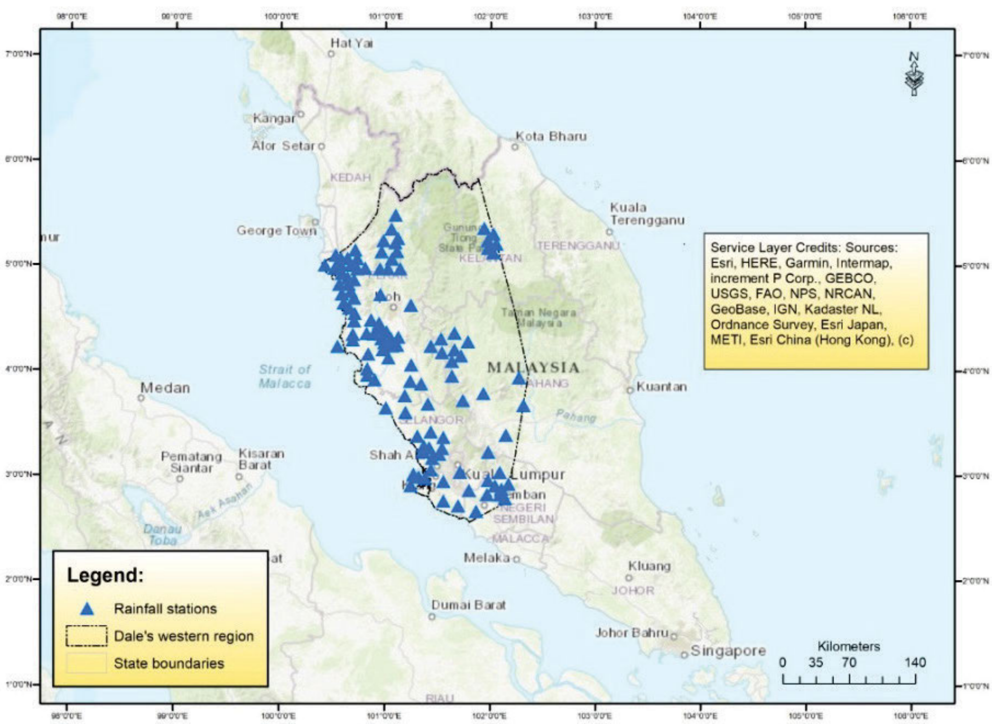

Fig. 2. Study areas and station placement; source: own elaboration

pollution or atmospheric pressure). In addition, this study also used a topological method to construct new rainfall boundaries to identify and update the geographical conditions of a given feature, such as the size that can be obtained from an area or the length of something. According to NASIR [2007], topology is the structure of vector data that models data by storing the topological information to identify the relationships between the spatial data of a place. This study also examined the change in the size of the dry and wet areas by using this method to obtain the actual area sizes to construct a new western rainfall region.

RESULTS AND DISCUSSION

The results of the analysis found that the pattern of rainfall distribution in the western region was inconsistent. Not all areas in the western region received between 2540 mm and 2794 mm of rain annually. In fact, there were also areas in the western region that had never received between 2540 mm and 2794 mm of rain. Areas that regularly received rain between 2540 mm and 2794 mm during the years 1960 to 2010 were Parit Buntar, Taiping, Kuala Kangsar, Ipoh, Teluk Intan, Tanjong Malim, Batang Kali, Subang, Petaling Jaya, Klang, Kajang, Bangi and Nilai.

Based on 51 years of rainfall data from 133 stations, the sizes of the western region areas have changed compared to Dale's 1959 study. This is because there were areas in the western region that had never received between 2540 mm and 2794 mm of rain. The areas that received rain between 2540 mm and 2794 mm only account for 90% (46413.6 km^2) of the area of Dale's western region, which is 51596.2 km^2 (Fig. 3).

This change in area size could be detected because of the use of rainfall data over a long period of time (from 1960 to 2010) compared to DALE [1959]. In addition, the large number of rain stations, which covered the entire area of the western region, also resulted in the construction of a new western rainfall region. A comparison between the new western region and Dale's western region is shown in Figure 4.

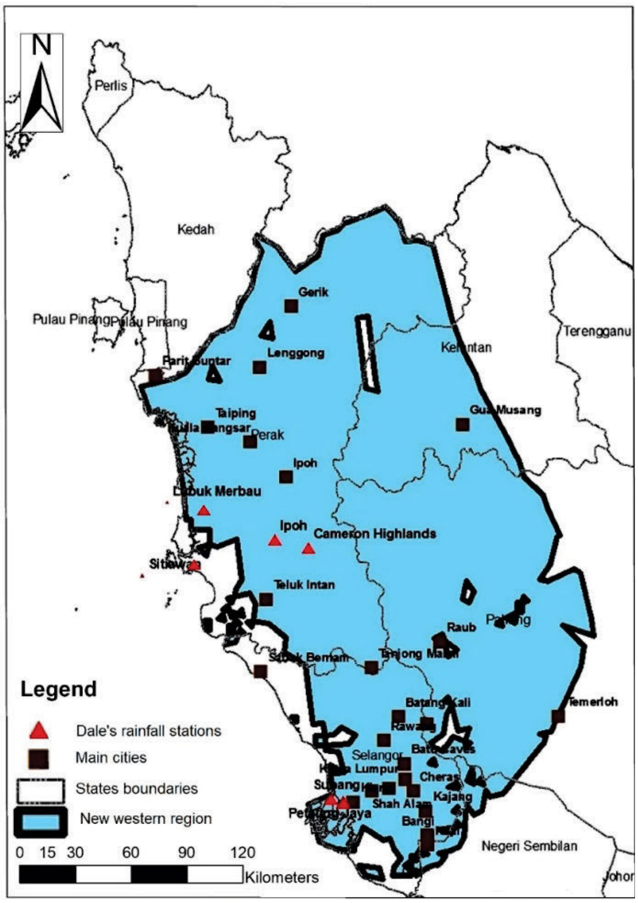

Fig. 3. New western rainfall region; source: own study

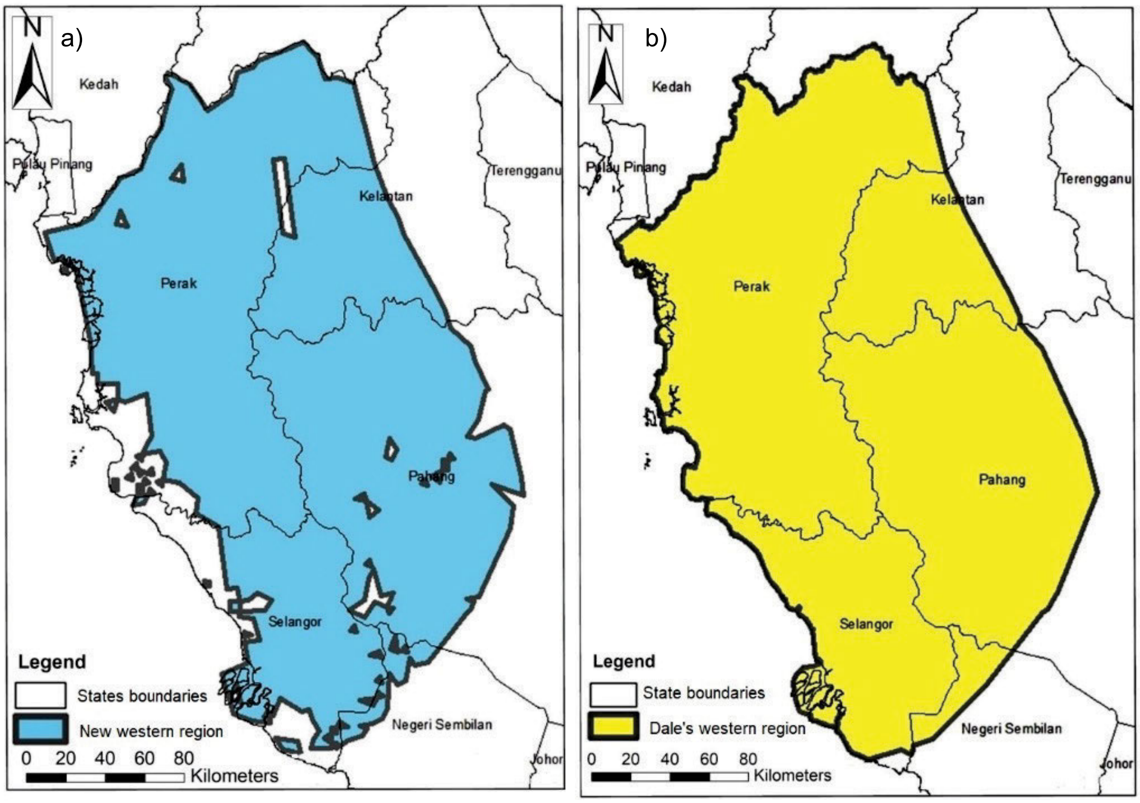

Fig. 4. Comparison between (a) the new western region and (b) Dale's western region; source: own study

Additionally, Figure 5 shows dry areas that received less than 2286 mm of rain and wet areas that received more than 2794 mm of rain in Dale's western region based on the rainfall data from 133 stations. Areas that were both dry and wet existed because of the overlapping of areas that received less than 2286 mm of rain (dry areas) and more than 2794 mm of rain (wet areas) every year for 51 years over the course of 1960 to 2010. As for the western area, which is the second most humid area, or a moderately wet area, it received between 2540 mm to 2794 mm of rain; the construction of specific areas could not be done. This is because there was no overlap in areas that received between 2540 mm to 2794 mm of rain every year for 51 years from 1960 to 2010.

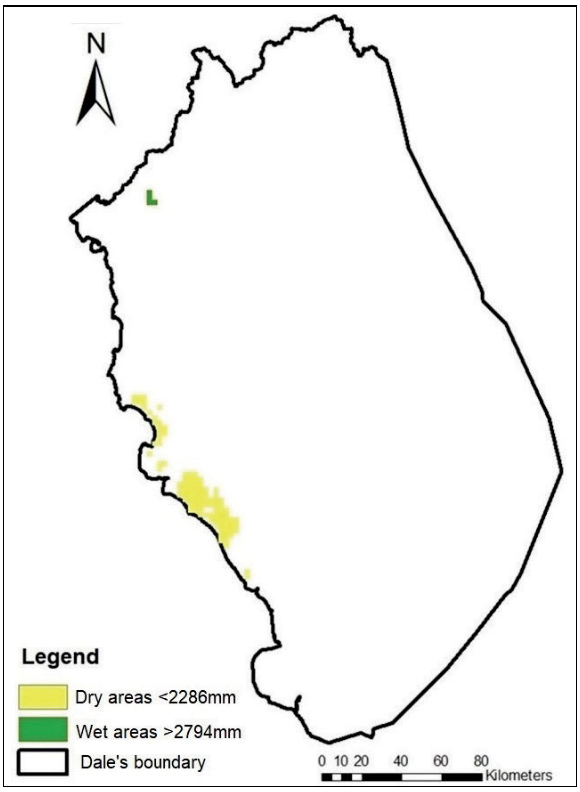

Fig. 5. Wet and dry areas formed in Dale's western region; source: own study

As a whole, the pattern of rainfall distribution in the western region was inconsistent. Not all areas in the western region received between 2540 mm and 2794 mm of rain every year. In fact, there were also areas in the western region that had never received between 2540 to 2794 mm of rain. The areas that received frequent rainfall, between 2540 mm to 2794 mm, in the years 1960 to 2010 were Parit Buntar, Taiping, Kuala Kangsar, Ipoh, Teluk Intan, Tanjong Malim, Batang Kali, the Cameron Highlands, Subang, Petaling Jaya, Klang, Kajang and Bangi. SHAHARUDDIN and NOORAZUAN [2006] state that changes in rainfall distribution patterns and variability can be attributed to local factors, such as the rapid development of an area, as well as global factors, such as climate change.

Based on the rainfall data for a period of 51 years from 133 stations, the area of the western region has changed compared to Dale's 1959 study. This is because there are areas in the western region that have never received between 2540 mm and 2794 mm of rainfall. The area that has received between 2540 mm and 2794 mm of rain is only 90% (46,413.6 km^2) of the area of Dale's western region, which is 51,596.2 km^2. This change in area could be detected because of the use of rainfall data over a long period of time (from 1960 to 2010) compared to that of Dale's study. In addition, the large number of rain stations, which covered the western region, have also enabled the construction of new western rainfall regions.

Changes in rainfall patterns from year to year can affect water resources, and these changes are a major problem faced by water resource planners. KHALIL [2020] explains that accurate knowledge of the rainfall regime is a prerequisite for effective water resource planning and management. ANAND and KARUNANIDHI [2020] emphasize that to plan and manage water resources, one must have a clear understanding of the rainfall distribution of an area.

CONCLUSIONS

In conclusion, there has been a reduction in the size of Dale's western region. The rainfall pattern has changed from 1960 to 2010. The results of this study might be able to help the Department of Irrigation and Drainage and the Malaysian Meteorological Department to identify the changes and climate diversity that affect water sources and impact human activities. In addition, the findings of this study can also help in the management of water resource planning in Malaysia by identifying the rainfall zones within a region, so that water resources can be fully utilized, especially in areas with water supply problems. Besides that, this study has also been able to assess the implications of the changes in hydro-climatological aspects (floods and water supply) that occur in Peninsular Malaysia, especially in the western region.

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