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Durian Yield Trends and Distribution Patterns in Peninsular Malaysia

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ABSTRACT

This study mainly aimed at gathering information on durian production trends and distribution in Peninsular Malaysia. Time series data from 2000 to 2017 involving planted areas and their respective production of durian were used for the analysis. The production trends and the magnitude of the slopes for all planted areas were then analyzed using Mann-Kendall and Sen's slope estimator. The results indicated that the hectarage of planted areas showed a downward trend in most parts except for Raub and Rembau districts. Despite the decrease in areas planted with durian, some areas exhibited an upward trend in annual production, particularly in the northern and central regions. This study also revealed that there was a shift in the distribution of durian production throughout the study period. These findings will be useful for policymakers and practitioners to improve durian orchard planning and management. However, future research should be conducted to determine the impact of climate variability on the shifting of durian production in Peninsular Malaysia.

Keywords: Durian production, durian planted area, Mann-Kendall, Sen's slope, variability

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INTRODUCTION

The durian (*Durio zibethinus* L.) also popularly known as "the king of tropical fruits" is one of the most economically important tropical fruits grown in Southeast Asia. Originated from Peninsular Malaysia and Borneo, its distribution has spread to Sri Lanka, Northern Australia, and Hawaii (Honsho et al., 2004). The main producers and exporters of durian are Thailand, Malaysia, and Indonesia while other countries in the region such as the Philippines and Vietnam produce durian for domestic consumption (O'Gara et al., 2004).

There are currently more than 72,391 hectares (ha) of durian planted across Malaysia. However, only 35,178 ha produced good quality durian yielding approximately 210,873 metric tons (MT) (Department of Agriculture [DOA], 2017). DOA (2017) also identified that the main producer states in Peninsular Malaysia were Pahang (Raub and Bentong, which produced about 43,712.7 MT), Perak (Batu Kurau produces 8201.3 MT) and Johor (Muar, Segamat, and Tangkak generated approximately 29,833.9 MT).

In 2016, more than 17,000 MT durians valued at about 17 million USD were exported, mainly to Singapore, Hong Kong, China, and the United States. However, the export volume decreased in 2017 to 14,000 MT with a value of 16 million USD. The fluctuation in the quantity of durian in the export and domestic markets is highly dependent on the season and the associated climatic problems (Ahmad et al., 2018).

Generally, durian fruiting seasons in Peninsular Malaysia are not similar among growing areas as they are influenced by the monsoon, dry spells, and the change from wet to dry weather conditions in a particular place (Chung, 2011). The change from wet and dry spells in monsoon weather systems is caused by solar radiation that triggers changes in land-sea temperatures (Huffman et al., 1997). In the case of durian, the increase and decrease in production trends are strongly related to changes in climatic conditions. Kukal and Irmak (2018) revealed that variations in crop yield could be due to factors such as technology, genetics, soil, field management and practices, fertilizers and climate. Among these variables, yield performance is largely influenced by climatic variability as it is the prominent driver in agricultural production. Unfortunately, unfavorable climatic conditions not only cause erratic production in terms of quantity but also affect the quality of durian (Hariyono et al., 2013).

Over the last two decades, the issue of climate change and its impact on agricultural production has been debated at many global and national forums. In Malaysia, several studies have reported that most crop commodities, particularly rice, are highly vulnerable to climate change (Al-Amin et al., 2011; Alam et al., 2012; Murad et al., 2010). Considering the negative impact of agricultural production due to climate change, many government agencies have developed mitigation and crop adaptation strategies to improve crop productivity.

However, these strategies encompass many scientific unknowns. This is particularly true for durian whereby the causes of durian yield variations due to climatic changes in Malaysia remain debatable. Therefore, studies on the distribution patterns and trend variation of durian in relation to changes in climatic conditions are the first step toward developing comprehensive and scientifically based strategies.

Examination of crop production trends can provide an insight into future crop production and can also be used for planning purposes (Abid et al., 2014). The information from yield trend studies can also help policymakers to propose policies that can improve food sustainability (Malhi & Kiran, 2015). Therefore, to support agricultural management decisions, trend analysis of crop production needs to be explored to include the spatio and temporal trends as a large variation may exist due to diverse climatic conditions (Yue & Hashino, 2003). Furthermore, time-series trends and change point detection analysis have become a popular approach due to the rapid changes in agricultural systems (Anderson, 2011; Jaiswal et al., 2008; Nikiforov & Basseville, 1993).

Trend analysis is an important tool that can extract underlying patterns of behavior and provide useful information on the possibility of tendency variation (Yue & Wang, 2004). Either parametric or non-parametric trend analysis can be used to detect trends and change points in time series data. However, many studies employ the non-parametric trend test as it has no limitation that requires data sets to be independent and normally distributed (Bandyopadhyay et al., 2009; Jaiswal et al., 2008; Shadmani et al., 2012).

The most widely used non-parametric trend test is the Mann-Kendall (MK) test, which evaluates the presence of statistically significant trends in the data. It is not influenced by outliers and is insensitive to the type of distribution (Ahmad et al., 2015, 2017; Chen et al., 2007; Hui-Mean et al., 2018). This method has been applied in a wide range of applications including climatological, hydrological, and agricultural studies.

The MK test evaluation is based on the correlation between the observed ranks and time sequences (Ahmad et al., 2017; Hamed, 2009; Yusof et al., 2012, 2014). The application of the MK test can be found in a report by Jain and Kumar (2012). They identified an increasing trend in temperature, rainfall, and a number of rainy days in India. Meanwhile, Yusof et al. (2012) produced a map that described the drought occurrence trend in Peninsular Malaysia using a rainfall dataset that was categorized based on the standardized precipitation index (SPI) and further verified according to the MK test. The map showed that major parts of Peninsular Malaysia experienced an increased period of dry spells.

Previous studies have used the MK test for climatic parameters including rainfall, wind speed, humidity, maximum and minimum temperature, and even the number of rainy days and occurrences of drought. However, the application of the MK test in agricultural production studies has not been emphasized as compared to climatic and hydrological studies. Interestingly, Poudel and Shaw (2016) investigated the seasonal and annual trends of climate variables as well as yields of rice, maize, millet, wheat, and barley using the MK test and the magnitude was quantified using Sen's slope. The findings were further correlated to observe the climate-crop yield relationship.

Therefore, it is important to examine the trend analysis of durian production in Malaysia. This study statistically analyzes the spatial and temporal trends in durian production as well as planted area variations. Hence, the objectives of this study are: (1) to identify the trend of planted areas and durian production in Peninsular Malaysia using the MK test, (2) to estimate the magnitude of changes using Sen's slope estimator, and (3) to display the results of trend analysis using a geostatistical method.

Study Region and Data Collection

In this study, crop data, including cultivated area and production quantity of durian in Peninsular Malaysia from 2000 to 2017, were collected from the Department of Agriculture, Malaysia. These data were taken from 88 districts in the 11 states namely, Terengganu, Selangor, Pulau Pinang, Perlis, Perak, Pahang, Negeri Sembilan, Melaka, Kelantan, Kedah and Johor as shown in Appendix 3.

Durian crop yield was measured in metric tons. The areas with the highest production for the total period were the Segamat and Muar districts in Johor, which produced from 419,000 to 465,000 metric tons of durian. This was followed by Raub, Batu Pahat and Pontian districts with a production of 368,000, 261,000 and 231,000 metric tons, respectively (DOA, 2017). Figure 1 is a map of total durian production for Peninsular Malaysia for the period.

A preliminary analysis was performed using basic descriptive statistics to obtain an early understanding of the data. A total of four areas with a very small or no cultivated area of durian namely Kuala Nerus (Terengganu), Mualim, Bagan Datoh, and Kampar (Perak) were identified and these were excluded from the study.

MATERIALS AND METHODS

Mann-Kendall Trend Test

The MK trend test (Kendall, 1975; Mann, 1945) is an applicable technique for identifying and interpreting the trend patterns in time series data, especially nonlinear trends (Zhai & Feng, 2009). The test is evaluated based on the correlation between the observed ranks and the order of time.

The application trend is expressed as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \quad (1)$$

$$sign(x_{j-}x_i) = \begin{cases} 1;\ x_i < x_j \\ 0;\ x_i = x_j \\ -1;\ x_i > x_j \end{cases} \quad (2)$$

$$V(S) = \frac{n(n-1)(2n+5)}{18} \quad (3)$$

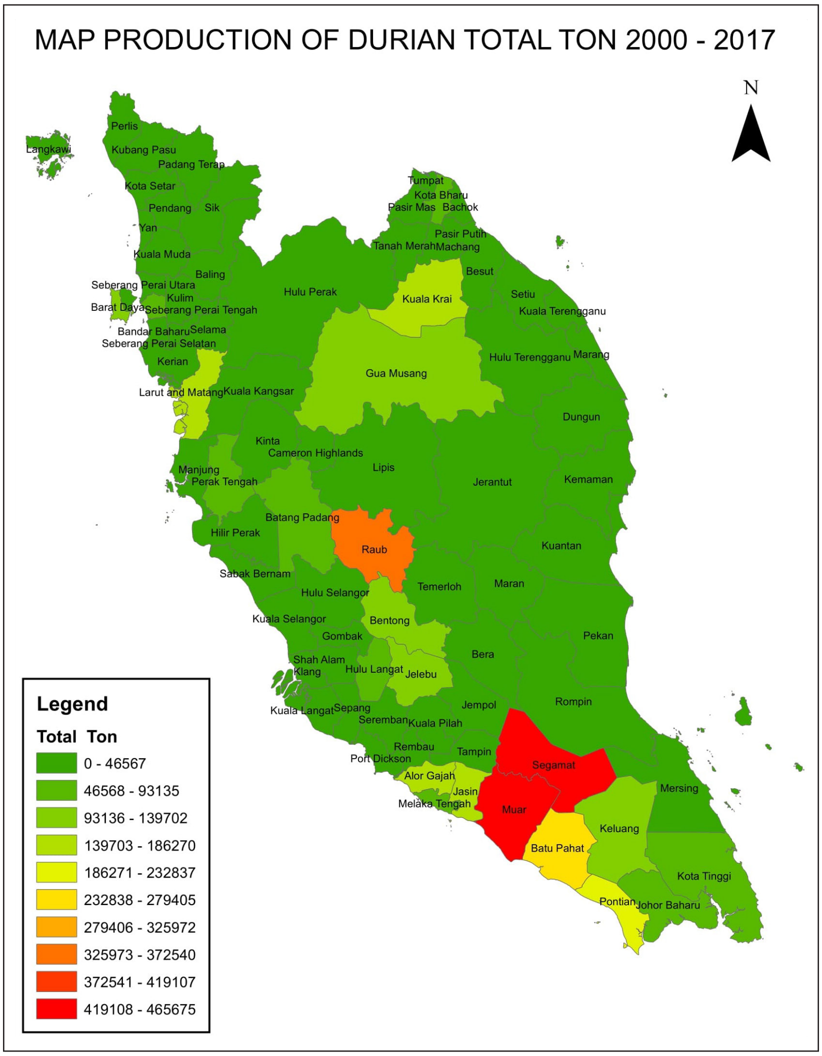


Figure 1. Total production (Metric Ton) of durian in Peninsular Malaysia (2000 to 2017)

$$Z = \begin{cases} \dfrac{(S-1)}{\sqrt{V(S)}}; S > 0 \\ 0; S = 0 \\ \dfrac{(S+1)}{\sqrt{V(S)}}; S < 0 \end{cases} \quad (4)$$

where $\{x_t : t = 1,2,\ldots,n\}$ is a time series for *n* sample size.

Positive values of Z indicate an increasing trend while negative values indicate a decreasing trend. The test hypothesis for this MK test is described as follows:

H_0: *There is no trend*
H_a: *A monotonic trend exists*

At the significance level $\alpha = 0.1$, if $|Z| > Z_{1-(\frac{\alpha}{2})}$, then H_0 is rejected and there is a significant trend in the time series (Partal & Kahya, 2006).

Sen's Slope Estimator

The direction and magnitude of the trend in the time series data were determined using Sen's slope (Sen, 1968). Sen's slope b is calculated using

$$b_i = \frac{x_j - x_i}{j - i}, i = 1,2,\ldots,N, \qquad j < i \tag{5}$$

The Sen's estimator of the slope is the median of these N values of b_i. The sign of b reflects the direction of the trend data while the value represents the magnitude. The trend analysis was conducted using the R Foundation for Statistical Computing Platform Version 3.4.0.

Map of Durian Production and Planted Area Trends

The map of these parameters was produced using ArcGIS 10 Software. All spatial data created were standardized using local projection Kertau RSO Malaya meters (EPSG:3168). To produce thematic maps, layer symbology was used to differentiate each unique value using districts as designated boundaries with appropriate color schemes to differentiate the level of intensity.

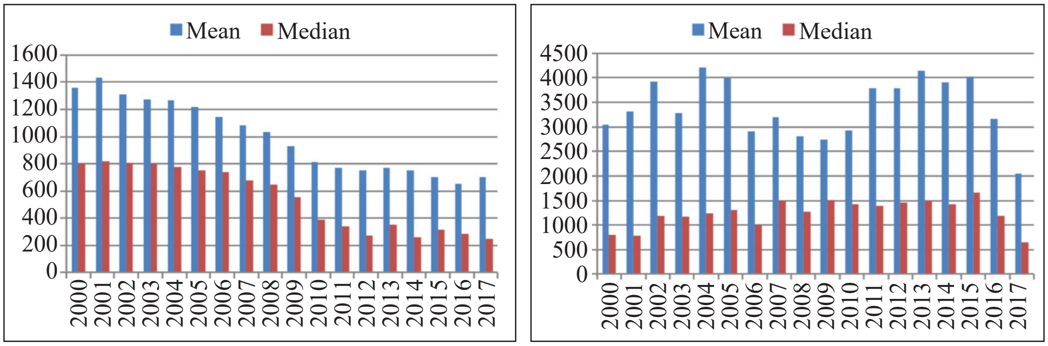
RESULTS AND DISCUSSION

Descriptive Statistics

The descriptive statistics computed the mean and median as a measure of the location while coefficients of variation, skewness, and kurtosis were used as a measure of variation. The yearly descriptive statistics values are summarized in Figure 2 and Figure 3.

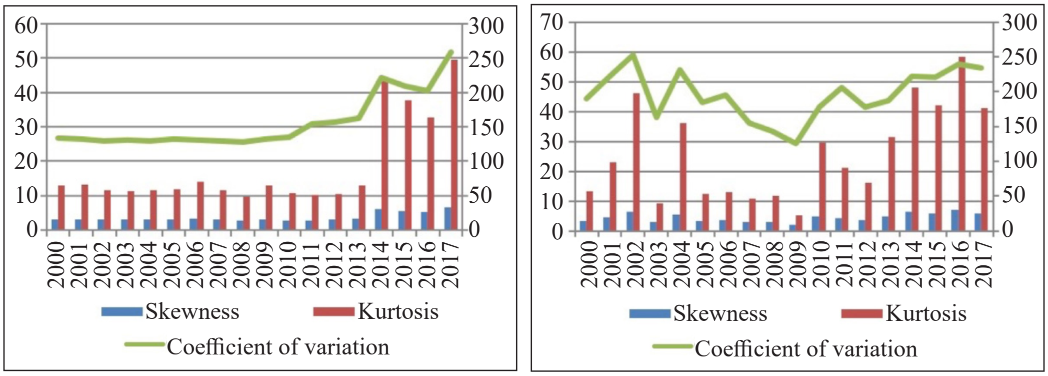
The Measure of Central Tendency

From Figure 2, the average area planted with durian was between 656 ha/year and 1,436 ha/year. Figure 2(a) reveals that the mean value of planted areas decreased annually. The largest area cultivated for durian was in 2001 (1,436 ha) and the smallest area was in 2016 (656 ha). The shrinkage of agricultural land in developing countries, including Malaysia, is generally due to the impact of higher demand for land to accommodate rising population, urban development,



(a) (b)

Figure 2. Mean and Median (a) planted areas and (b) production in Peninsular Malaysia (2000-2017)



(a) (b)

Figure 3. Coefficient of skewness, kurtosis, and variation for (a) planted areas and (b) production in Peninsular Malaysia (2000-2017)

expansion of industrial sectors, and government policy that encourages non-agricultural industries (Masoudi et al., 2017; Tahir & Malek, 2017; Xiao et al., 2006).

The mean of durian production (Figure 1(b)) ranged from 2,052 MT/year to 4,210 MT/year. The highest durian production was recorded in 2004 while the lowest was in 2017. As previously mentioned, the production of durian is greatly influenced by the monsoon and this causes fluctuation in the annual mean production of durian in Malaysia. Durian trees require an average of two to four weeks dry season to induce flowering and wet weather is required during fruit developmental stages for optimal production (Safari et al., 2018).

As can be seen in Figure 2, similar to mean values, the median for both planted areas and production showed similar trends. A higher mean value than the median indicated that the annual distribution of planted areas and production was right-skewed. Under this positively skewed distribution, the extreme values occurred on the right side and with a higher magnitude. That is most of the areas and production were in the lower group, which forms the bulk of the distribution toward the left side. However, some of the areas experienced very high production and larger cultivation areas, as shown by the tail of the distribution, which was extended further to the right side.

Measure of Variability

The coefficient of variation (CV) is a unitless indicator that describes the dispersion of the variables with respect to the mean (Maarof et al., 2012). Thus, the CV for the study period will represent the annual irregularity in durian cultivated areas and production between years. However, our results revealed that the CV of areas planted with durian was rather homogenous and ranged between 128 to 162 throughout the study period, except for the last four years (Figure 2(a)). The smallest CV value (128.2) occurred for 2008 while the highest was in 2017 (257.7). On the other hand, the CV values for annual durian production showed a large variation between years. The smallest value was recorded in 2009 (125.5) and the largest CV was in 2002 (252.5) (Figure 3(b)).

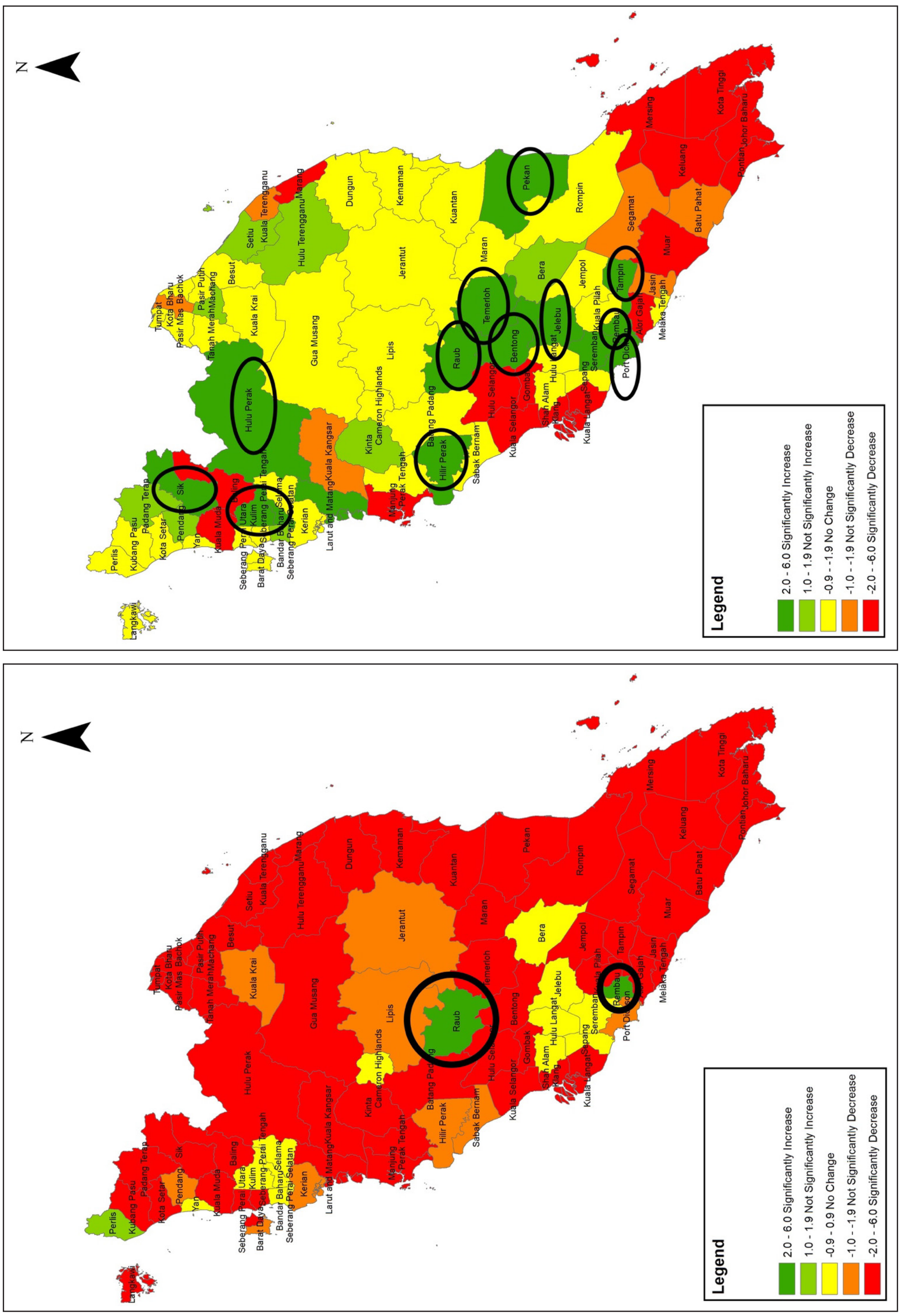
The coefficient of skewness is normally used to verify the degree of asymmetry of the distribution around the mean. The value of skewness that is near 0 indicates the data is normally distributed. The positive and negative values of skewness indicate the distribution is right or left-skewed, respectively (Maarof et al., 2012). The value of skewness for both planted areas and production was all positive ranging from 2.81 to 6.55 and 2.2 to 7.2, respectively. The results proved that the annual distribution of planted areas and production were right-skewed. The highest values of skewness for planted areas and production were for 2017 and 2016, respectively, indicating a positively skewed distribution with the tail extending to the right (Yusof et al., 2012).

Similarly, the value of kurtosis can be used to determine the peak of the distribution with the kurtosis value of the normal distribution is three. The kurtosis values hectarage and production are all positive in the range of 9.65 to 49.5 and 5.32 to 58.2, respectively (Figure 3). The highest values were in 2017 and 2016 for durian planted areas and production, respectively. This implied a leptokurtic distribution in which the data set tends to have a distinct peak near the mean with a heavy tail (Yusof et al., 2012). Meanwhile, the smallest value of kurtosis (9.65) in 2008 for planted areas and durian production (5.32) in 2009 implied that the data set tended to have a flat peak near the mean.

Trend analysis was conducted for planted areas and production with respect to each district in Peninsular Malaysia across the study period. The results of the MK test for planted areas and production are summarized in Figure 4. The darker regions indicate significant trends while the lighter regions indicate non-significant trends; no changes in trends were detected.

The magnitude of the trends is presented in Appendix 1 and Appendix 2, showing decreasing trends with a 95% significance and no changes in trend except for the circled regions (Figure 4(a)). Raub (PH09 in Pahang) and Rembau (NS05 in Negeri Sembilan) showed a significant upward trend regarding planted areas with magnitudes of 515.70 ha and 18.69 ha per year, respectively. Raub has been recognized as a major durian production area in which 90% of residents are engaged in durian planting. This area is also famous for the Musang King variety of durian ("Discover Raub", 2017). The mountainous terrain with cool night temperatures appears to be suitable for durian cultivation.

A total of 15 out of 84 districts involving four states, namely, Pahang, Kedah, Perak, and Negeri Sembilan, recorded a significant upward trend (95% statistical significance) in durian production for the 17 years (Figure 4(b)). The districts are Bentong, Raub, Pekan, Temerloh (Pahang), Kulim, Sik (Kedah), Larut Matang, Selama, Hulu Perak, Hilir Perak, Bandar Bahru (Perak), Jelebu, Rembau, Seremban, Port Dickson (Negeri Sembilan).



(a) (b)

Figure 4. Summary of MK results for (a) planted areas and (b) production in Peninsular Malaysia (2000-2017)

The observed trends for planted area and production for all districts can be further categorized into six cases: (i) increasing trend in planted areas and decreasing trend in production, (ii) decreasing trend in planted areas and increasing trend in production, (iii) increasing trend in both but more significant for production, (iv) decreasing trend in both but more significant for production, (v) increasing trend in both but more significant for planting areas, and (vi) decreasing trend in both but more significant for production. Decreasing the amount of planted areas would lead to reduced production. However, in the 15 districts mentioned above, our results indicated an upward trend in production although hectarage of planted areas showed shrinking trends. We assumed that this is due to more efficient crop management practices by commercial farmers in these areas. We suggest that more attention should be given to improve productivity in some districts of Johor (Muar and Tangkak districts in the southern part of Peninsular Malaysia) that used to be major durian production areas.

Based on the map of total durian production in 2000 and 2017 (Figure 5), the density of durian production is found to have changed and shifted across districts. In 2000, production was relatively higher in the southern parts of Peninsular Malaysia while in 2017, the highest durian production was observed in the central and eastern coastal parts of the region. The higher productivity was assumed to be related to profuse flowering and fruiting seasons in these areas. Some areas experienced more than one fruiting season and would, therefore, have higher production. Furthermore, changing climate patterns, especially the long drought period, could have changed durian production patterns. The occurrence of drought normally triggers the flowering of durian.

A recent study based on drought probability analysis (using the first-order homogenous Markov chain model), suggested that the northwest and middle regions were more susceptible to moderate and severe drought, respectively (Sanusi et al., 2015). Annual extreme and partial duration series analysis revealed that the northern regions have a higher number of dry days compared to more dry spells in the middle regions. Furthermore, according to Hui-Mean et al. (2018), Pahang state has experienced a downward trend in climatic water balance (CWB), in which more dry days occurred. This climatic condition has increased the chances of off-season durian flowering and eventually increased annual production.

Despite climate variability, the shift in durian production pattern in Peninsular Malaysia from the southern to the central region is related to the mountainous demographic of Pahang. Besides the environmental suitability for durian cultivation in Pahang, the hill-grown durian is believed to yield more fruits with great texture of flesh and good taste. Furthermore, to meet the export demand, the Department of Agriculture has initiated durian cluster projects in Pahang and Perak (DOA, 2017). The shift of durian production may also be

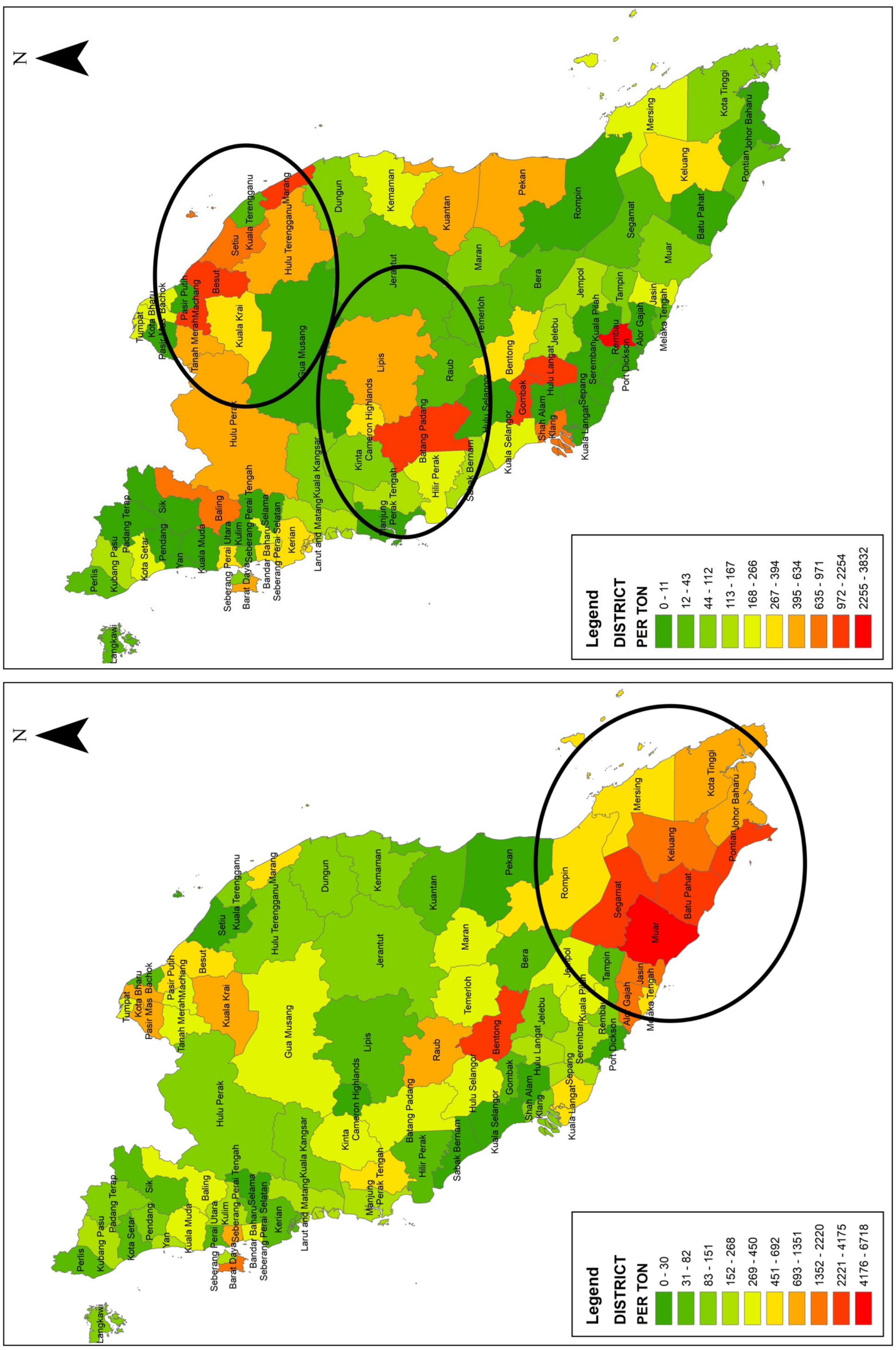


Figure 5. Total Production of durian in (a) 2000 and (b) 2017

due to the changing of other crops after its failure due to soil unsuitability, especially in Johor. Urban and industrial development in Johor also contributes to the decreasing in durian cultivation.

The detected trends and their corresponding magnitudes for planted areas and production in all districts are illustrated in Appendix 1 and Appendix 2, respectively.

CONCLUSION

Trend analysis and distribution patterns for durian production are important to determine the tendency of production in different locations and at different times. The hectarage of durian was also included in the analysis and a decreasing trend was revealed in the hectarage of most durian planted areas in Peninsular Malaysia except for Raub (PH09 in Pahang) and Rembau (NS05 in Negeri Sembilan). However, the annual durian production showed an upward trend, particularly in most of the districts in Pahang, Perak, and Negeri Sembilan. Based on magnitudes obtained from Sen's slope estimator, the area with the highest increase in production was found to be Raub (2,326 MT/year) followed by Larut Matang and Selama (728.67 MT/year) and Bentong (486.25 MT/year). However, the downward trend of annually planted areas suggests decreased production in Peninsular Malaysia, but some areas showed an increase in annual production, especially in the northern and central regions. The present analysis provides valuable information on the distribution patterns of durian production in Peninsular Malaysia. It also provides evidence that there are other external factors such as localized climatic conditions that could shift the distribution of durian production.

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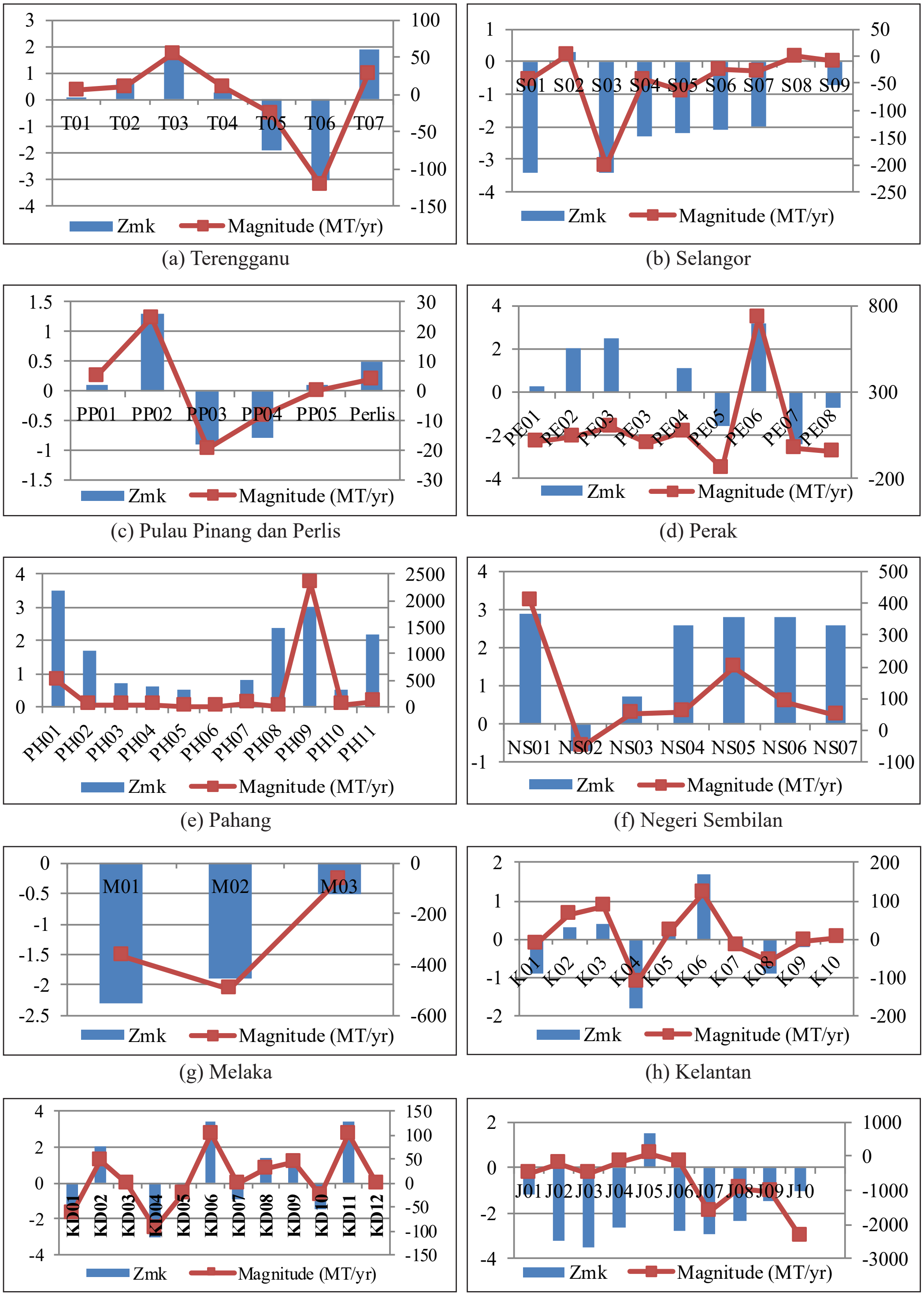
APPENDICES

Appendix 1. Trend and magnitude for durian planted area



(a) Terengganu (b) Selangor

(c) Pulau Pinang dan Perlis (d) Perak

(e) Pahang (f) Negeri Sembilan

(g) Melaka (h) Kelantan

(g) Kedah (h) Johor

Appendix 2. Trend and magnitude of durian production

Appendix 3
List of districts involved in this study

	DITRICT	STATE		DITRICT	STATE
T01	BESUT	TERENGGANU	NS01	JELEBU	NEGERI SEMBILAN
T02	DUNGUN		NS02	JEMPOL	
T03	HULU TERENGGANU		NS03	KUALA PILAH	
T04	KEMAMAN		NS04	PORT DICKSON	
T05	KUALA TERENGGANU		NS05	REMBAU	
T06	MARANG		NS06	SEREMBAN	
T07	SETIU		NS07	TAMPIN	
S01	GOMBAK	SELANGOR	M01	ALOR GAJAH	MELAKA
S02	HULU LANGAT		M02	JASIN	
S03	HULU SELANGOR		M03	MELAKA TENGAH	
S04	KLANG		K01	BACHOK	KELANTAN
S05	KUALA LANGAT		K02	GUA MUSANG	
S06	KUALA SELANGOR		K03	JELI	
S07	PETALING		K04	KOTA BAHRU	
S08	SABAK BERNAM		K05	KUALA KRAI	
S09	SEPANG		K06	MACHANG	
PP01	BARAT DAYA	PULAU PINANG	K07	PASIR MAS	
PP02	SEBERANG PERAI SELATAN		K08	PASIR PUTIH	
PP03	SEBERANG PERAI TENGAH		K09	TANAH MERAH	
PP04	SEBERANG PERAI UTARA		K10	TUMPAT	
PP05	TIMUR LAUT		KD01	BALING	KEDAH
Perlis	PERLIS	PERLIS	KD02	BANDAR BAHRU	
PE01	BATANG PADANG	PERAK	KD03	KOTA SETAR	
PE02	HILIR PERAK		KD04	KUALA MUDA	
PE03	HULU PERAK		KD05	KUBANG PASU	
PE03	KERIAN		KD06	KULIM	
PE04	KINTA		KD07	LANGKAWI	
PE05	KUALA KANGSAR		KD08	PADANG TERAP	
PE06	LARUT MATANG SELAMA		KD09	PENDANG	
PE07	MANJUNG		KD10	POKOK SENA	
PE08	PERAK TENGAH		KD11	SIK	
PH01	BENTONG	PAHANG	KD12	YAN	
PH02	BERA		J01	BATU PAHAT	JOHOR
PH03	CAMERON HIGHLAND		J02	JOHOR BAHRU	
PH04	JERANTUT		J03	KLUANG	
PH05	KUANTAN		J04	KOTA TINGGI	
PH06	LIPIS		J05	KULAI	
PH07	MARAN		J06	MERSING	
PH08	PEKAN		J07	MUAR	
PH09	RAUB		J08	PONTIAN	
PH10	ROMPIN		J09	SEGAMAT	
PH11	TEMERLOH		J10	TANGKAK	