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Relationship of Rainfall Distribution and Water Level on Major Flood 2014 in Pahang River Basin, Malaysia

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Abstract

Climate change gives impact on extreme hydrological events especially in extreme rainfall. This article discusses about the relationship of rainfall distribution and water level on major flood 2014 in Pahang River Basin, Malaysia in helping decision makers to flood management system. Based on DID Malaysia rainfall station, 56 stations have being use as point in this research and it is including Pahang, Terengganu, Kelantan and Perak. Data set for this study were analysed with GIS analysis using interpolation method to develop Isohyet map and XLstat statistical software for PCA and SPC analyses. The results that were obtained from the Isohyet Map for three months was mid-November, rainfall started to increase about in range of 800mm-1200mm and the intensity keep increased to 2200mm at mid-December 2014. The high rainfall intensity sense at highland that is upstream of Pahang River. The PCA and SPC analysis also indicates the high relationship between rainfall and water level of few places at Pahang River. The Sg. Yap station and Kg. Serambi station obtained the high relationship of rainfall and water level with factor loading value at 0.9330 and 0.9051 for each station. Hydrological pattern and trend are extremely affected by climate such as north east monsoon season that occurred in South China Sea and affected Pahang during November to March. The findings of this study are important to local authorities by providing basic data as guidelines to the integrated river management at Pahang River Basin.

Keywords: Isohyet map; flood 2014; rainfall distribution; GIS; Pahang River

1. Introduction

Flood is one of the most common natural disasters across the globe, jeopardizing settlements along the flood plains and being considered a continued hazard for humanity. Malaysia is no exception due to its annual experience with flood during the monsoon season. According to Sulaiman *et al*., 2015, the flood event is becoming an often disaster in Malaysia. The land use cover due to deforestation and massive development of the areas has become a perception to the researcher that it is the main reason that contribute to the increased of results in flood frequency and severity. Stream flow of rivers can be used as an indicator for the flood event (Kamarudin *et al*., 2015a). Pahang Basins are one of the areas that received highest total rainfall during north east monsoon period about 40 per cent of the total rainfall annually (Lun *et al*., 2011; Gasim *et al*., 2013). According to Adnan and Atkinson (2008), climate change and weather are important roles in various fields such as hydrology, epidemiology and environment sustainability.

Flood that occurred on December 2014 was one of the worst floods that ever hit the East Coast of Peninsular Malaysia that consist of Pahang, Terengganu and Kelantan. According to Utusan Online (2014), Pahang major flood started on mid-December and end on mid-January 2015 that provide a lot of precipitation to Pahang River Basin which indirectly caused the overflow of Pahang River, resulted on flood event.

Rainfall distribution is very important in the study of flood disaster. According to Department of Drainage and Irrigation (DID, 2010), there are three main sources of flooding such as heavy local rainfall, extreme river discharge and sea wave from South China Sea. Rainfall is the main sources of water input to the watersheds were is influence by the water storage and discharge of a river especially during heavy rainfall event. Therefore, the study on the impact of rainfall and run-off is very important in order to elaborate the cause of flood event (Obled *et al*., 1994; Ogden and Julien, 1993; Yue and Wang, 2004).

Besides that, rainfall also plays an important role during major flood event. In the case of rainfall distribution similar to the direction of the main stream, the flood peak is higher when it is moving in the opposite area or direction (Kamarudin *et al*., 2015b; Vega *et al*., 1998).

Statistical tools are commonly used to detect the significant of trends in climate and hydrological field by using non-parametric analysis such as Principle component analysis, Statistical process control, and the parametric analysis such as descriptive statistic and student's *t*-test. In statistical tools, nonparametric test is considered better and it displays much insensitivity to outlier unlike parametric test (Mann, 1945). The application of environ metric, a branch of environmental analytical chemistry and the use of multivariate statistical modeling and data treatment was reported to be the best method in analysing a large complex environmental monitoring data (Kamarudin *et al*., 2015c; Kendall, 1975; Liu *et al*., 2003).

The purpose of this study is to analyse the rainfall pattern and distribution throughout Pahang River Basin as to indicate the factors lead to flood 2014. Heavy rainfall that surge Pahang River Basin in late 2014 leaved a huge impact to the flood event that caused extraordinary flood water level in Pahang River Basin. The study of rainfall distribution during the flood event is crucial because it can provides numerous influence to better understanding of rainfall in the basin and leads to better decision making in order to mitigate the factors of flooding event. In addition, there is further investigation being carried out in order to examine the effects of south-west monsoon season on November to March for every year to the parameter that been studied in Pahang River.

2. Materials and Methods

2.1 Study area

Pahang River is one of the largest river basins in Peninsular Malaysia. Pahang River is located at longitude 101° 30' 00" E to 103° 30' 00" E and latitude 3° 00' 00" N to 4° 45' 00" N. Pahang River is the major river system in Pahang River basin that started from the Titiwangsa mountain range to the South China Sea.

This research involves the rainfall distribution of 56 stations that are located in Pahang, Terengganu, Kelantan and Perak states. All these stations are located at Pahang state and nearby states which are involved to obtained more accuracy on rainfall distribution.

2.2 Data

In this study, the secondary data that is being used are from four different stations that have been set up by DID Malaysia to monitor the rainfall data of Pahang River Basin and its border. According to Juahir *et al*., 2011, in hydrological procedure no. 4 in DID Malaysia had mentioned some of the data that were obtained and recorded may not have quality secondary date that was due to the error of the gauge, inaccuracy in data collection and rain gauge recorders.

The records from prior to 1970 were operated by using a manual gauge and after that it is being upgraded with automatic gauge is whether it is an underestimation or improper reading of the parameter.

2.3 Isohyet method

According to Jayawardene *et al*. (2005), Isohyet method is used to estimate the mean precipitation across an area. The method is by drawing lines of equal precipitation on a map by using Geographical Information System (GIS). This method uses the topographic map and other hydrological data of Pahang River Basin to yield reliable estimation. Isohyets are contours of equal precipitation that analogous to contour lines on a topographic map. The stations of rain gauge that available along Pahang River Basin are being mark on the topographic map to observe the areas that deliver the highest equal precipitation. Isohyets lines then being draw based on the interpolation between rain

gauge stations on the map to differentiate the area of the precipitation focused. Whiles constructing Isohyets, it is assumed that the rainfall between two stations varies linearly, unless it is indicates otherwise due to changes in topography. The rainfall data of Pahang River Basin is obtained from the Department of Drainage and Irrigation (DID) Malaysia from upstream to the downstream of Pahang River that started at Gagau Mount and ended at Pekan, Pahang.

2.4 Statistical analysis

In this study, Principle Component Analysis (PCA) analysis was performed to the data set to exclude insignificant data. This analysis is based on eigenvalue criteria where value >1 is considered as significant and a new group of variables built based on the resemblance of the entire data set (Juahir *et al*., 2011). The PCs generated by PCA are sometimes not readily interpreted. It is advisable to rotate the PCs by varimax rotation to obtain new groups of variables called varimax factors (VFs). The correlation between the VFs and the original variables is given by the factor loading, while the individual transformed observations are called factor scores (Simeonov *et al*., 2000). The VF coefficients having a correlation >0.75 are considered 'strong', 0.74 - 0.50 are considered 'moderate' and 0.49 - 0.30 are considered 'weak' significant factor loadings. For this study, factor loading >0.75 both positive and negative will be considered (Hamilton *et al*., 2001). Data were statistically calculated and analysed using the Xlstat version 2014.

Statistical Process Control (SPC) is a method used for quality control of the data sets. SPC is used in this study to conform product or the data sets in order to ensure the data sets used is reliable and meet the specification needed for further analysis such as Isohyet and PCA. The data sets that been used for SPC analysis were rainfall and water level data. In this case, rainfall and water level data from several stations is being test to provide support for the argument in PCAs and Isohyet method.

3. Results and Discussion

3.1 Isohyet map of rainfall intensity

Based on this study, GIS analysis using interpolation method has been done to develop Isohyet map for spatial distribution of local climate in Pahang River Basin on major flood 2014. The Isohyet method has been used to divide the area by its intensity of the rain and using contour as the dividing lines of the differences between the intensity of rainfall. Fig. 1 shows the rainfall intensity of Pahang River Basin in November 2014. Rainfall play an important role in life as a fresh water source but it is also a factor that leads to the most floods. Annually, Peninsular Malaysia will be hit by heavy rainfall during end of year. However, in 2014 the rain intensity is extraordinarily high due to the monsoon and a new moon phenomenon (Umar *et al*., 2015).

Base on Fig. 1, the rainfall intensity on November 2014 is high and focused on Kuantan, Pekan and a few districts of Pahang close to Selangor state. According to Jamaludin *et al*. (2010), during mid-November 2014, the heavy rainfall that hit Pahang especially in Pahang River Basin caused a flash flood in several places including Pekan, Chini, Jerantut and Kuala Tahan in National Park of Malaysia. Heavy rainfall was also found to hit the Kuantan River Basin, i.e. the nearby river basin, in the capacity range about 250mm to 350 mm during mid-November 2014 (Fig. 1(a)), It can be concluded, the river basin that nearby Pekan area also affected the flood occurs in Pekan that located in Pahang River Basin. Besides that, the borders of Perak, Kelantan and Pahang that are located at highland such as Brinchang and Cameron Highland, the intensity of rainfall increased dramatically at the range of 1600mm to 1700mm.

The increased in rainfall intensity in December 2014 especially during mid-December had caused flood in several areas such as Jerantut, Maran and Temerloh. Other areas in Peninsular Malaysia such as Kelantan have hit by a major flood due to heavy rains. Based on the Isohyet map, high rainfall intensity in December 2014 was focused at Terengganu and Kelantan border with the range of rainfall intensity was 1600mm to 2300mm (Fig. 1(b)). Temerloh, Jerantut and National Park also obtained a high intensity of rain at the range of 1200mm to 1400mm. The high intensity of rains at the highland of National Park and Gagau Mount, the flow of surface runoff to the upstream of Pahang River was high and caused the overflow of flood water to the nearby areas. Other areas such as at the downstream of Pahang River show quite high rainfall intensity at the range of 300mm to 800mm especially in Chini and Pekan. The flow of flood water from upstream and middle stream caused the over flow of river at downstream such as at Chini, Pekan that suffered by heavy flood at 8 to 9 metres high of water level.

During Pahang flood disaster in 2007, heavy rainfalls that started in mid-December until mid-January is one of the factors that lead to flood. High rainfall intensity also suffered by area at the border with Perak at Brinchang and Cameron Highland. Rainfall intensity in capacity about 350mm to 450mm in November 2014 and 400mm to 600mm in December 2014 lead the high velocity of flood water flow from Cameron highland in to Semantan River then met with the Pahang River in Temerloh area, that received high river flow due to the heavy rainfall in Jerantut and National Park in Tembeling River. Pahang River in Temerloh lead to major flood occurred in Temerloh. The rainfall event in the same direction or area with the main stream will peak the flood alongside the stream.

During January 2015, the rainfall intensity in Pahang State focused in Pekan located in Pahang River Basin. However, the rainfall cumulative intensity still pouring down in few areas that heavily affected by flood such as National Park, Jerantut, Temerloh, Cameron Highland especially in Brinchang and Chini in capacity range about 60mm to 120mm (Fig. 1(c)). Pekan districts was hit by flood later after upstream and middle stream compared to flood in Kelantan that hit almost entire Kelantan areas in short time. For the other places such as central area of Pahang State and upstream area of Pahang River, the rainfall intensity has dropped to the range of 400mm to 120mm in the blue area in Fig. 1.

3.2 Rainfall and water level relationship analysis

Fig. 2 and Table 1 shows the confirmation of the Isohyet analysis has been proved by using statistical analysis through Statistical Process Control (SPC) and Principle Component Analysis (PCA).

Based on Fig. 2, the results shows that the water level of Pahang River increased as the rainfall intensity increased through SPC analysis. The *p*-value of the analysis is *0.0001* less than *0.05* (Table 2). That means have a significant correlation between water level and rainfall. The mean of the correlation was at 25 values show that the water level of 25 m is the optimum range of the rainfall intensity that raises the water level in Pahang River.

Based on the outcome of PCA analysis in Table 1, there were several changes of the value at the water level and rainfall data station in Temerloh, Kuala Lipis, Sg. Yap, Kg. Merting, and Kg. Serambi. The factor loading at the studied station indicates that there are relationship between water level and rainfall intensity at that particular area. The station that has the most closed relationship between water level and rainfall is Sg. Yap station that obtained 0.9330 for factor loading. Kg. Serambi station also the highest connection connection of rainfall and water level with factor loading value at 0.9051.

This result shows that the increase on rainfall intensity will affect the water level of Pahang River. This analysis also shows that irregular variation of water level and rainfall intensity. The peak value of maximum and minimum that always changing also shows the condition of local climate and river hydrology that always changes due to the natural process that cannot be controlled by human (Singh, 1998; Mohd Saudia *et al*., 2015). The peak value of maximum is positive while minimum value is negative referred to water level and rainfall data.

For the data distribution in this analysis, Fig. 3 shows the data distribution of relationship between water level and rainfall of Pahang River. The distribution of the data shows that Kg Serambi, Kuala Lipis, Sg. Yap and Temerloh station was the most significant correlation of the two parameters (water level and rainfall data). The percentages of significant are 73.79% that is high due to the rainfall amounts that lead to the water level increased.

Table 1. Factor loading values of water level-rainfall from Principle Component Analysis (PCA)

	F1	F2	F3	F4	F5	F6	F7
tmr (Temerloh)	**0.8503**	-0.0863	0.0454	0.3784	0.3475	-0.0544	-0.0247
lp (Lubuk Paku)	0.2586	0.7821	0.5649	-0.0428	0.0209	0.0006	0.0030
yap (Sg. Yap)	**0.9330**	0.0101	-0.0752	0.1164	-0.1213	0.3088	0.0118
tahan (Kuala Tahan)	0.3616	-0.5873	0.7010	-0.1810	0.0038	0.0146	0.0046
lipis (Kuala Lipis)	**0.8867**	0.0626	-0.2204	-0.3434	0.0502	-0.0324	-0.1994
merting (Kg. Merting)	**0.8928**	-0.0290	0.0303	0.2217	-0.3441	-0.1828	-0.0079
serambi (Kg. Serambi)	**0.9051**	0.0490	-0.2204	-0.2732	0.0814	-0.0612	0.2115

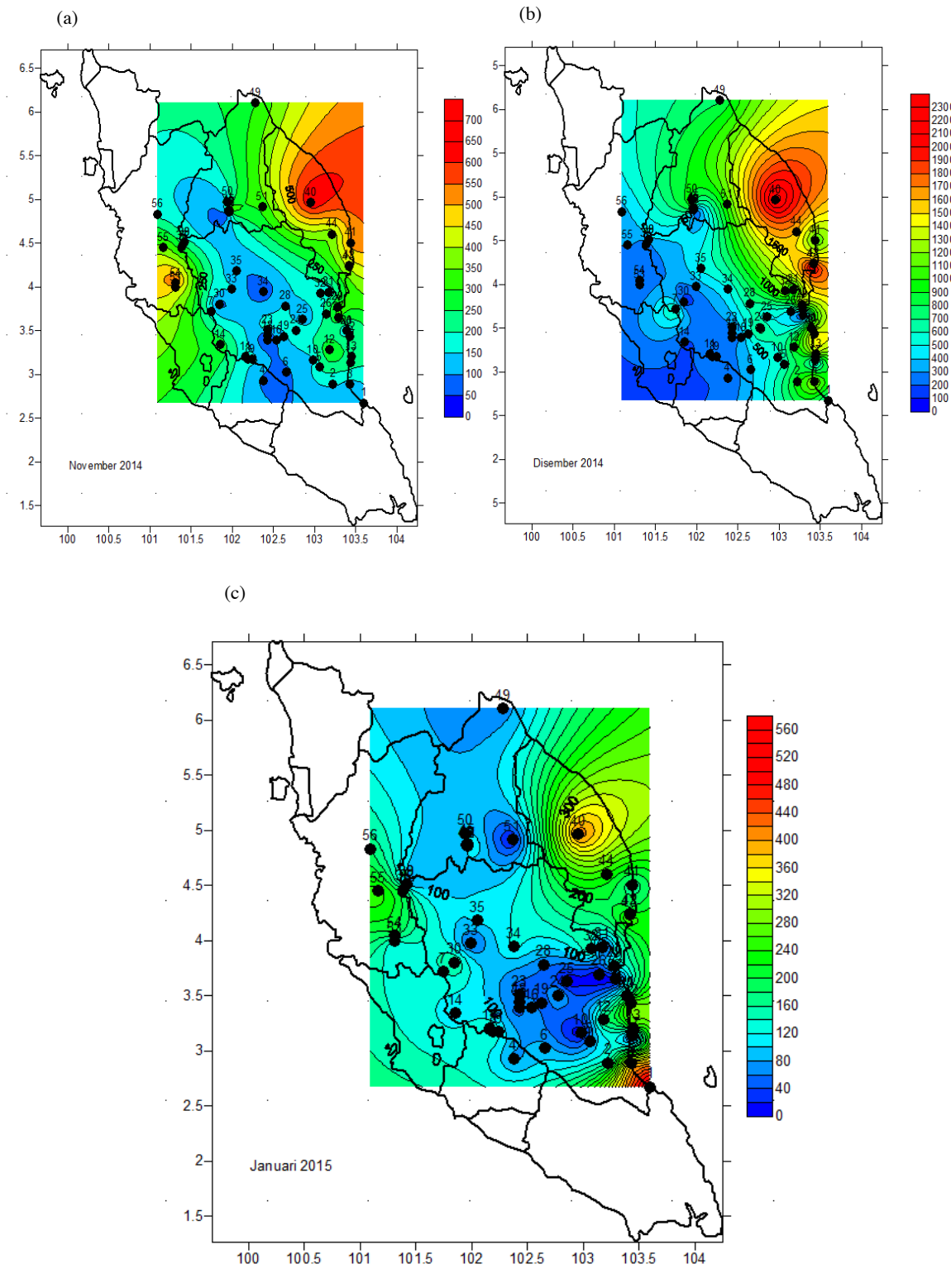

Figure 1. Cumulative rainfall distribution of Pahang river basin from (a) November 2014, (b) December 2014 and (c) January 2015

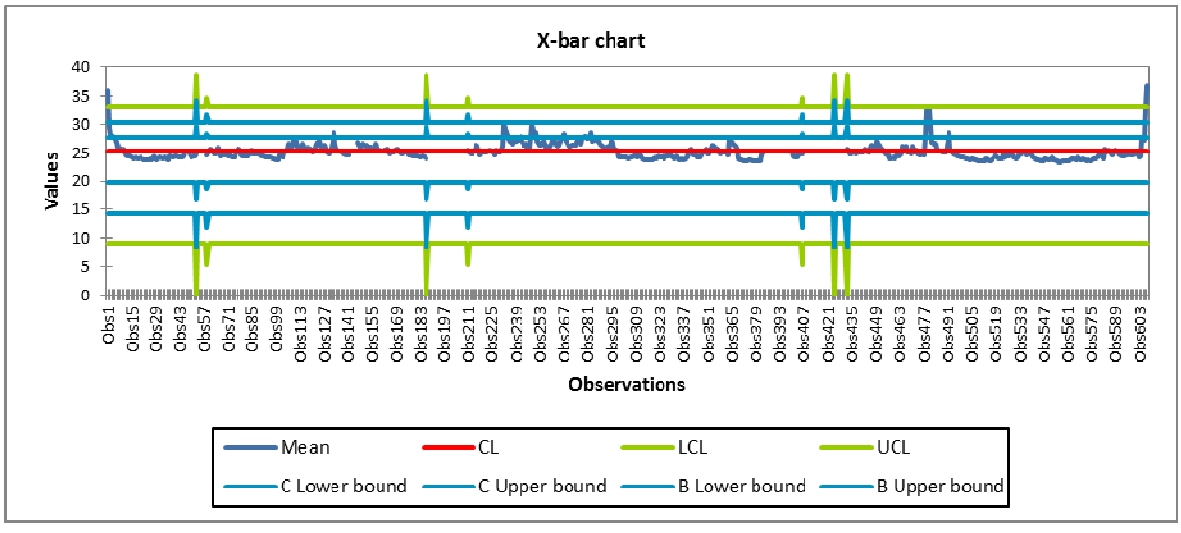

Figure 2. Statistical Process Control (SPC) of water level-rainfall in Pahang River

4. Conclusions

For overall, applications of the Geographical Information System (GIS) and statistical analysis in this study actually help in order to fulfil the objective of this study. Major flood event that hit Pahang River Basin is caused by high rainfall intensity especially in highlands area. The met of water in high velocity from Semantan River and Pahang River also lead to the major flood event in Pahang. Using interpolation method in GIS to Isohyet map, the distribution and the intensity of rainfall in Pahang River Basin is easily indicated and analysed to have a clear picture of the factors that lead to the disaster event. Rainfall distribution in Pahang River Basin that focused in upstream area leads to the initial flood in Jerantut and Kuala Lipis. Rainfall distribution analysis is very important in order to identify the area that is hit by heavy rainfall that leads to flood. Non-parametric analysis such as PCA and SPC also play important features in this study. The statistical analysis is required to evaluate the hydrological data and present the best tools and information for decision making. This study is also performed in order to help in flood assessment and forecasting of flood event in the future.

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Table 2. Sphiro- Wilk test of water level- rainfall from SPC analysis

Normality tests:	
Shapiro-Wilk test:	
W	0.3262
p-value	< 0.0001
alpha	0.05

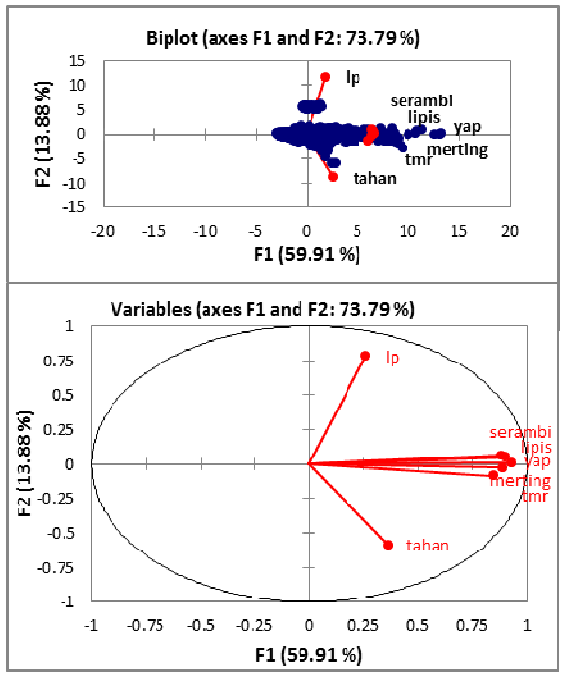

Figure 3. Biplot and variables distribution

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