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Preface: International Conference on Science and Applied Science (ICSAS) 2021

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Preface: International Conference On Science And Applied Science (ICSAS) 2021

International Conference on Science and Applied Science (ICSAS) 2021 was the sixth conference which was organized by the Physics Department, Universitas Sebelas Maret. On this occasion, the ICSAS 2021 was held virtually on April 6th, 2021, due to the COVID-19 pandemic. The ICSAS 2021 conference is aimed to bring together scholars, leading researchers, and experts from diverse backgrounds and application areas in science. Special emphasis is placed on promoting interaction between the science theoretical, experimental, and other topics related to physics.

In ICSAS 2021, there are 8 parallel sessions and four keynote speakers. The keynote speakers provided to talk about the current research such as the application of multiferroic material for high speed devices; following the second keynote were speaker talk the magnetic-interaction of the interlayer systems in nanometer order. Other keynote speaker provided to talk solution of Klein Gordon equation coupled directly by quadratic vector and scalar potential using NU function analysis and its application for optical properties. The final keynote was provided to talk regarding superconductivity: first invention to current application. While for the conference participants, there is 303 participant which was submitted abstract via the conference system. Then, the 186 full papers have been submitted from the participant, and after the reviewed process, 136 papers have been presented in the ICSAS 2021. And then for the final decision, 116 papers published in AIP Conference Proceedings.

We would like to thank all of the participants attending this conference and also to the committee for their contribution to this high-level conference and its overall success. We also would like to thank the reviewers for their positive contribution to maintain the quality of the articles presented at this conference.

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Profile analysis in clustering with Hotelling's T-square statistics

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Dewi R. S. Saputro, Alfian F. Hadi and Gusti N. A. Wibawa

Profile Analysis in Clustering with Hotelling's T-Square Statistics

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Abstract. Cluster analysis is a multivariate technique that groups objects based on their characteristics. For instance, it groups the most closely similar objects in the same cluster, thereby forming high internal homogeneity and external heterogeneity. Validation of the grouping results, carried out through profile analysis, is important to obtain the best partition that fits the basic data. Therefore, this study determined the profile analysis in clustering using Hotelling's T-square statistics on profile analysis and its application to rainfall data. Equivalent profile analysis with mixed ANOVA was used to test for hypothesis on the mean value of multiple variables (multivariate) using graph principles. In profile analysis, data plots were carried out to compare between groups of 3 patterns visually, namely, profile alignment, coincide, and alignment with the flat axis. These patterns were further validated using Hotelling's T-squared statistical test, which is a multivariate extension of the common one-sample or paired student t-test and used when the number of response variables is one or more. The result showed that the data is close to normal multivariate.

INTRODUCTION

Data is a necessity for the wider community, both in academia, companies, health, and government. In statistics, knowledge is related to the process of collecting, analyzing, and making conclusions based on data sets consisting of more than one variable. One of the methods used to discuss more than one variable simultaneously is the Multivariate analysis. Furthermore, one of the techniques discussed in this analysis is clustering, which is commonly used for statistical data analysis in various fields, such as machine learning, image analysis, pattern recognition, data mining, and bioinformatics [1].

Cluster analysis is carried out to partition a set of objects into 2 or more groups based on the similarity of their special characteristics [2]. There are two types of clustering methods, namely hierarchical and nonhierarchical [3]. It is important to validate the results of these clustering methods to obtain the best partition that fits the basic data [4]. This process, which is known as profile analysis, is carried out by assuming the object's profile is multidimensional and composed of several components with the composing variables expressed as feature vectors. According to Watkins et al., a feature vector represents the profile of a population [5].

Equivalent profile analysis with mixed ANOVA is a part of hypothesis testing that is used to determine the mean value of multiple variables (multivariate) using the graph principle [6]. It is also used to measure the amount of variability associated with level and pattern effects and to identify whether two or more groups of test takers have significantly distinct or similar score profiles. Profile analysis is also used to assist the interpretation and analysis of individual patterns. It can be held either between or within an individual, allowing the interpretation of test scores

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either inter and intra individual as well as the quantification of the similarity degree of observed profiles [7]. Several statistical frameworks have implemented profile analysis [8]. This is caused by this which has a main focus on identifying profile patterns and classifying ndividuals based on the observed score profiles [9].

The F statistic was used in the statistical profile analysis based on Hotelling T^2 and the t statistic. Meanwhile, in this research, a discussion was conducted on profile analysis in clusters using the most frequently used version of Hotelling's (1931). The T^2statistic computed two independent groups of subjects are tested on two or more dependent variables [10]. T^2 can be conceptualized as a multivariate analogue of an independent groups t-test, as a partner of multivariate analysis of variance with two groups, and as an equivalence of their discriminant analysis [11].

MATERIAL AND METHODS

Material

t, F, and Multivariate Normal Distribution

Hotelling's T-squared is essensial in distributing a set of statistics which are a natural generalization of student's T-distribution as the basis. This process involves undertaking tests to determine differences between multivariate means of various populations, where univariate problems using a t-test. It is comparable to the F distribution and is named after its developer, Harold Hotelling.

Student's T distribution[12] is calculated as follows:
$Z \sim \mathrm{N}(0,1)$ and $V \sim \chi^2(v)$, where Z and V are distributed from the transformation, assuming they are independent.

$$T = \frac{Z}{V/v}$$

Student's T distribution with freedom degree of v expressed by $T \sim t(v)$.

$$f(t;v) = \frac{\Gamma\left(\frac{v+1}{2}\right)}{\Gamma\left(\frac{1}{2}\right)} \frac{1}{\sqrt{v\pi}} \left(1 + \frac{x^2}{v}\right)^{-(v+1)/2}$$

F Distribution [13]. If $V_1 \sim \chi^2(v_1)$ and $V_2 \sim \chi^2(v_2)$ are independent then random variable

$$X = \frac{V_1/v_1}{V_2/v_2}$$

has the following probability density function for $x > 0$

$$g(x; v_1, v_2) = \frac{\Gamma\left(\frac{v_1+v_2}{2}\right)}{\Gamma\left(\frac{v_1}{2}\right)\Gamma\left(\frac{v_2}{2}\right)} \left(\frac{v_1}{v_2}\right)^{\frac{v_1}{2}} x^{\left(\frac{v_1}{2}\right)-1} \left(1 + \frac{v_1}{v_2}x\right)^{-(v_1+v_2)/2}$$

This is known as ***Snedecor's F distribution*** with freedom degree v_1 and v_2, and expressed by $X \sim F(v_1, v_2)$.

Multivariate Normal Distribution (Bain & Engelhardt [13]). A pair of continuous random variables $X_1, \ldots, X_n$ is said to have **multivariate normal** or ***k*-normal variate distribution** assuming the joint probability density function has the following form

$$f(x_1, \ldots, x_k) = \frac{1}{\sqrt{(2\pi)^2|\boldsymbol{V}|}} \exp\left[-\frac{1}{2}(\boldsymbol{x}-\boldsymbol{\mu})'\boldsymbol{V}^{-1}(\boldsymbol{x}-\boldsymbol{\mu})\right]$$

with $\boldsymbol{x}' = (x_1, \ldots, x_k), \boldsymbol{\mu}' = (\mu_1, \ldots, \mu_k)$, and $\boldsymbol{V} = \{\mathrm{Cov}(X_i, X_j)\}$, and for $\mu_i = E(X_i)$ and $\boldsymbol{V}$ is a nonsingular covariance matrix $k \times k$

Methods

This is theoretical research consisting of journals, discussion forums, workshops, and textbooks on rainfall in Indramayu, West Java. The related material examined is the hypothesis, the Hotelling distribution(T^2), and its relation to profile analysis. Several steps were taken to reduce the multivariate normal probability, t, and F distributions used in this research, describe the hypothesis, and relate it to the t and F distribution. Steps were also taken to prove hypotheses to profile alignment, coincide, and perform analysis of results.

RESULTS AND DISCUSSION

Profile analysis is related to the condition in which a series of p treatments is applied to 2 or more populations (groups). Therefore, assumptions are needed to perform this analysis because the various groups (populations) are independent of each other. Furthermore, all responses of the variables need to be expressed in the same unit, hence they can be compared and added up, while the error value is multinormally distributed with a mean of 0 and σ^2 variance.

Profile Analysis

In the profile analysis, the following 3 questions are proposed to be tested through a hypothesis, namely profile alignment, coincide, and alignment.

a. Is the mean value profile between treatment groups similar or parallel? (Hypothesis 1)
b. If similar, are the mean value profiles of the treatment groups at the same level or coincide? (Hypothesis 2)
c. If similar, does the mean value profile of the treatment groups be at a constant level for each treatment group or have the same magnitude? (Hypothesis 3)

Question (a) relates to the interaction between treatment groups with a certain distance, assuming they possess parallel or average treatment. Question (b) relates to the similarity hypothesis of the effects of each treatment on each group, which tends to be similar, assuming the average for each treatment is the same. Question (c) relates to the overall treatment that has the same average for each group. The 3 hypotheses were tested sequentially, and assuming the first hypothesis (alignment) after being tested turns out to be rejected, the tests for hypotheses 2 (similarity) and 3 (horizontal) will no longer apply. Each hypothesis test is given in the text description.

Hypothesis Testing in Profile Analysis

The general model in profile analysis expressed in the matrix equation is $\boldsymbol{Y} = \boldsymbol{XB} + \boldsymbol{\varepsilon}$ where ***X, B,*** and $\boldsymbol{\varepsilon}$ denote the design, parameter, and error matrices with dimensions *(N x i)*, (*i x p),* and *(N x p).* Meanwhile, Y is a matrix of dependent variables dimension *(N x p)*. Also, $p,\ i,\ n_i, and\ N$ are the numbers of dependent variables, treatment (population), observations in the treatment-i, and is the total number of observations.

$$\begin{bmatrix} y_{11} \\ \vdots \\ y_{1n_1} \\ y_{21} \\ \vdots \\ y_{2n_2} \\ \vdots \\ y_{i1} \\ \vdots \\ y_{in_j} \end{bmatrix} = \begin{bmatrix} 1 & \cdots & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & \cdots & 0 & \cdots & 0 \\ 0 & \cdots & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & 0 & \cdots & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & 0 & \cdots & 1 \end{bmatrix} \begin{bmatrix} \mu_{11} & \mu_{12} & \dots & \mu_{1p} \\ \mu_{21} & \mu_{22} & \dots & \mu_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ \mu_{i1} & \mu_{i2} & \cdots & \mu_{ip} \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_{11} \\ \vdots \\ \boldsymbol{\varepsilon}_{1n_1} \\ \boldsymbol{\varepsilon}_{21} \\ \vdots \\ \boldsymbol{\varepsilon}_{1n_2} \\ \vdots \\ \boldsymbol{\varepsilon}_{i1} \\ \vdots \\ \boldsymbol{\varepsilon}_{in_j} \end{bmatrix}$$

Based on the general form model, hypothesis testing is arranged as follows:

Parallel Test

The general form of hypothesis for parallelism test is,

$$H_{01} = \begin{bmatrix} \mu_{11} - \mu_{12} \\ \mu_{12} - \mu_{13} \\ \vdots \\ \mu_{1(p-1)} - \mu_{1p} \end{bmatrix} = \begin{bmatrix} \mu_{21} - \mu_{12} \\ \mu_{22} - \mu_{13} \\ \vdots \\ \mu_{2(p-1)} - \mu_{2p} \end{bmatrix} = \cdots = \begin{bmatrix} \mu_{i1} - \mu_{12} \\ \mu_{i2} - \mu_{13} \\ \vdots \\ \mu_{i(p-1)} - \mu_{1p} \end{bmatrix}$$

or for 2 independent samples of the population, the hypothesis is written as $H_{01}\colon \boldsymbol{C\mu_1} = \boldsymbol{C\mu_2}$ where $\boldsymbol{C}$ is a contrast matrix, hence it creates an equation as in the general form of the parallelism hypothesis.

$$\boldsymbol{C}_{((\boldsymbol{p-1})\boldsymbol{xp})} = \begin{bmatrix} -1 & 1 & 0 & \cdots \\ 0 & -1 & 1 & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \dots \end{bmatrix}$$

For independent samples $x_1$and x_2, from 2 populations (treatments), a mean value is made for each variable using the Hotelling T^2 test written as follows

$$T^2 = (x_1 - x_2)' \left[\left(\frac{1}{n_1} + \frac{1}{n_2}\right) \boldsymbol{C\hat{\Sigma}C'}\right]^{-1} \boldsymbol{C}(x_1 - x_2)$$

with $C^2 = \frac{(n_1+n_2-2)(p-1)}{n_1+n_2-p} F_{p-1,\, n_1+n_2-p\,(\alpha)}$; $\boldsymbol{\hat{\Sigma}}$ is the covariance matrix (covariance) of the variables. The null hypothesis is rejected if the value of $T^2 > C^2$ and C^2 is dependent on the value of table $F_{p-1,\, n_1+n_2-p\,(\alpha)}$. related to Hotelling T^2, and the distribution is described as follows.

Hotelling's T-squared distribution is essential because it is a set of statistics that are a natural generalization of students' T distribution. In particular, it appears in multivariate statistics in performing tests of the differences between population means, where tests for the univariate problem use t-test. Furthermore, it is comparable to the F distribution and is named after its developer Harold Hotelling.

In hypothesis testing, Hotelling (T^2) is a multivariate probability distribution is a generalization of the student t-distribution and is closely related to the F distribution. It serves to recognize the difference between 2 experimental groups, where each consisting of two or more varieties, statistically and simultaneously analyzed. Hotelling's test on 2 independent samples is one of the multivariate comparative statistical analysis techniques used to compare the 2 groups of samples studied, and it is a development of the 2 independent sample t-test. The difference lies in the number of dependent variables. In the t-test, the 2 independent samples only have 1 dependent variable, while the Hotelling test has more than 1.

If $x_{11}, x_{12}, \dots, x_{1n_1} \sim \boldsymbol{N}_{n_1}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ and $x_{21}, x_{22}, \dots, x_{2n_2} \sim \boldsymbol{N}_{n_2}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ is an independent sample from a multivariate normal distribution, the mean and covariance are calculated as follows:

$$\bar{x}_1 = \frac{1}{n_1} \sum_{i=1}^{n_1} x_{1i}\,;\ \bar{x}_2 = \frac{1}{n_2} \sum_{i=1}^{n_2} x_{2i}$$

$$\boldsymbol{\hat{\Sigma}}_{x_{1i}} = \frac{1}{n_1 - 1} \sum_{i=1}^{n_1} (x_{1i} - \bar{x}_1)(x_{1i} - \bar{x}_1)'\,;\ \boldsymbol{\hat{\Sigma}}_{x_{2i}} = \frac{1}{n_2 - 1} \sum_{i=1}^{n_2} (x_{2i} - \bar{x}_2)(x_{2i} - \bar{x}_2)'\,;$$

$$\boldsymbol{\hat{\Sigma}} = \frac{(n_1 - 1)\boldsymbol{\hat{\Sigma}}_{x_{1i}} + (n_2 - 1)\boldsymbol{\hat{\Sigma}}_{x_{2i}}}{n_1 + n_2 - 2}$$

Hotelling distributed with parameters p and m is written as follows:

$$t^2 = \frac{\boldsymbol{n_1 n_2}}{\boldsymbol{n_1 + n_2}} (\bar{x}_1 - \bar{x}_2)' \boldsymbol{\hat{\Sigma}}^{-1} (\bar{x}_1 - \bar{x}_2) \sim\ T^2(p, \boldsymbol{n_1} + \boldsymbol{n_2} - 2)$$

The relationship with the F distribution is described as follows.

$$\frac{\boldsymbol{n_1} + \boldsymbol{n_2} - p - 1}{(\boldsymbol{n_1} + \boldsymbol{n_2} - 2)p} t^2 \ \sim F_{p, \boldsymbol{n_1} + \boldsymbol{n_2} - 1 - p}$$

The sample from this population can be extended to p observations.

This statistical non-null distribution is a non-central F distribution (chi-square ratio of non-central and central)

$$X = m\boldsymbol{d}^{\boldsymbol{T}} \boldsymbol{M}^{-\boldsymbol{1}} \boldsymbol{d} \sim T^2(p, m)$$

If $X \sim T^2_{p,m}$ then $\frac{m-p+1}{pm} X \sim F_{p,m-p+1}$ with $F_{p,m-p+1}$ is the F distribution with parameter p and $m - p + 1$.

Hotelling's-T can be transformed to an F-statistic. Similar to the t-test, the T value is determined and compared with table value. The null hypothesis is rejected, assuming the calculated value is greater than the table statistic. For simplify this calculation, Hotelling's t^2 is first transformed to an F-statistic as follows:

$$F = \frac{n_1 + n_2 - p - 1}{p(n_1 + n_2 - 2)} T^2 \sim F_{p, n_1 + n_2 - p - 1}$$

where n_1 *and* n_2 are sample sizes, p is the number of variables sample, $n_1 + n_2 - p - 1$ is degrees of freedom.

$$F = \frac{n_1 + n_2 - p - 1}{p(n_1 + n_2 - 2)} T^2 \sim F_{p, n_1 + n_2 - p - 1}$$

Coincident Test

The general form of the hypothesis for the coincide test is as follows: $H_{01} = \begin{bmatrix} \mu_{11} \\ \mu_{12} \\ \vdots \\ \mu_{1p} \end{bmatrix} = \begin{bmatrix} \mu_{21} \\ \mu_{22} \\ \vdots \\ \mu_{2p} \end{bmatrix} = \cdots = \begin{bmatrix} \mu_{i1} \\ \mu_{i2} \\ \vdots \\ \mu_{ip} \end{bmatrix}$

Profiles coincide with each other assuming the total of the mean values of each population is $\mu_{11} + \mu_{11} + \mu_{11} + \mu_{11} + \mu_{12} + \cdots + \mu_{1p} = \mu_{21} + \mu_{22} + \cdots + \mu_{2p} = \cdots = \mu_{i1} + \mu_{i2} + \cdots + \mu_{ip}$. The form of the hypothesis is $H_{02} = \boldsymbol{1}'\boldsymbol{\mu_1} = \boldsymbol{1}'\boldsymbol{\mu_2} = \ldots = \boldsymbol{1}'\boldsymbol{\mu_p}$ which is examined after the parallelism test of the hypothesis is rejected. The test statistic for the coinciding hypothesis with 2 independent samples from the population is written as follows:

$$T^2 = \boldsymbol{1}'(\bar{x}_1 - \bar{x}_2)' \left[\left(\frac{1}{n_1} + \frac{1}{n_2} \right) \boldsymbol{1}'\widehat{\boldsymbol{\Sigma}}\boldsymbol{1} \right]^{-1} \boldsymbol{1}'(\bar{x}_1 - \bar{x}_2).$$

Retesting is carried out for the combination of the samples used, assuming the observation consists of more than 2 independent samples. In other words, each test is carried out by 2 samples from the individual population.

The hypothesis is rejected assuming the value of the test statistic is $T^2 > t^2_{n_1+n_2-2}(\alpha/2)$ or $T^2 > F_{p-1, n_1+n_2-p}(\alpha)$. Furthermore, the profiles tend to coincide, supposing all observations come from the same normal population. Next, another test is carried out on the similarity test (level) of all the variables.

Similarity Test (Level)

If parallelism and coincide are acceptable, then the mean vector of μ (from 2 normal populations) is estimated using $n_1 + n_2$ observation, with the formula written as follows:

$$\bar{x} = \frac{\sum_{j=1}^{n_1} x_{1j} + \sum_{j=1}^{n_2} x_{2j}}{n_1 + n_2} = \frac{n_1}{n_1 + n_2} \bar{x}_1 + \frac{n_1}{n_1 + n_2} \bar{x}_2$$

If the profile is the same, then $\mu_1 = \mu_2 = \cdots = \mu_p$ and the null hypothesis is written as follows:

$$H_{03} = \begin{bmatrix} \mu_{11} \\ \mu_{12} \\ \vdots \\ \mu_{1p} \end{bmatrix} = \begin{bmatrix} \mu_{21} \\ \mu_{22} \\ \vdots \\ \mu_{2p} \end{bmatrix} = \cdots = \begin{bmatrix} \mu_{i1} \\ \mu_{i2} \\ \vdots \\ \mu_{ip} \end{bmatrix} \text{ or } H_{03} = \boldsymbol{C\mu} = \boldsymbol{0}$$

and the test statistics, for $F = (n_1+n_2)\bar{x}'\boldsymbol{C}'[\boldsymbol{CSC}']^{-1}\boldsymbol{C}(n_1+n_2)\bar{x}$, the null hypothesis is rejected if $F > F_{p-1,n_1+n_2-p}\,(\alpha)$.

Application

The profile analysis application was determined at 27 rain gauge stations in Indramayu Regency based on data from rainfall observations from 1980 to 2000. This process was carried out using the ZOM formation technique with the clustering algorithm by previously conducting Principal Component Analysis (PCA) to reduce the data variables, complete linkage method, and distance calculation using Euclid distance. The process of clustering rainfall obtained 5 PCA with a total diversity. Table 1 shows that the 4 main components of 84.99% led to the formation of 3 new clusterings. A complete description of this clustering was explained in the research carried out by [14].

TABLE 1. Rainfall clustering

Cluster	Rainfall Stations
1	Anjatan, Bugel TL Kacang Kr.Asem LW Semut Wanguk GBWetan Cikedung Tugu Sukadana Bondan Smr Watu Kroya Tamiyang
2	SL Darma, Gantar
3	Jatibarang Juntinyuat Ked Bunder Lohbener Sudi Mampir Krangkeng SudiKamp Losarang Cidempet Bangkir Indramayu

A test carried out using Hotelling's Trace technique found that the 3 clusters were significantly different. This is shown by the calculation results that $T^2 = 8.451 > 4{,}225 = C^2$. The plot of the 3 clusters is shown in Figure 1.

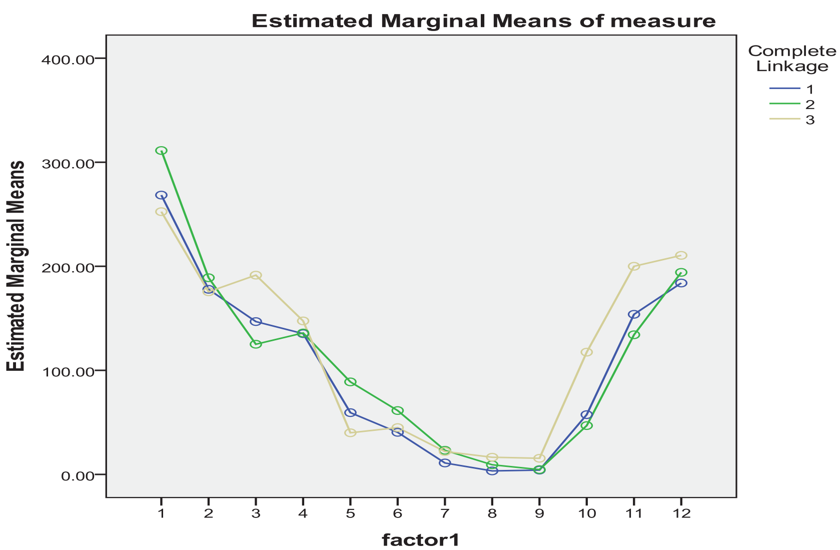

FIGURE 1. Rainfall pattern for clusters 1,2, dan 3

Figure 1 visually indicates similarities in clusters 1 and 2. Furthermore, profile analysis can be carried out to determine the similarities between clusters.

Profile analysis

Profile analysis is used to determine the similarity between the clusters formed to understand profile similarity estimates. The results show that 6.73890544> 4.08 with $\alpha = 5\%$, therefore, the null hypothesis is rejected, which indicates that the clustering is significantly different. The rainfall clustering mapping is shown in Figure 3.

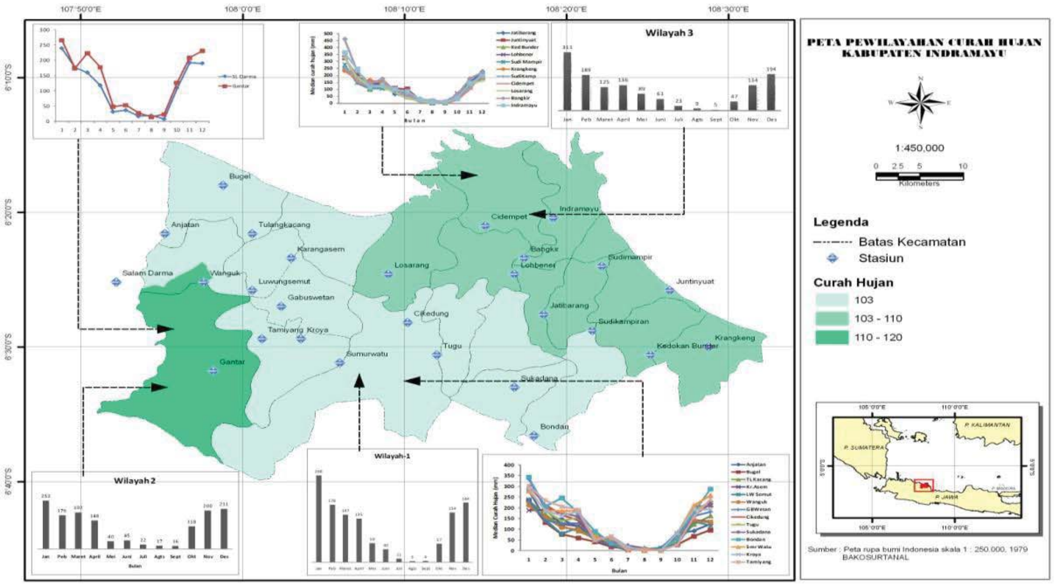

FIGURE 2. Rainfall clustering

In Figure 2 shows that the highest rainfall average occurred in clusters 3, followed by clusters 2 and 1. The clustering of Figures 2 and 3 is in accordance with the research results on rainfall patterns in Indonesia by [15]. In Java Island, the rainfall type is monsoon, where the highest occurs in January and December and the lowest in June-August [16]. Cluster 3 has lower average rainfall from August to December than others. Meanwhile, from January to February and May to June, it experienced higher rainfall than the other two clusters, as shown in Figure 2. The highest average rainfall occurs in January in cluster 3. The area with the largest average annual rainfall in cluster 2 was located in the southwest, south, and borders of Sumedang and Majalengka Regencies.

Lastly, the category of wet, humid, and dry months is arranged as shown in Table 2. It is based on Schmidth-Fergusson with dry (BK), humid (BL), and wet (BB) months having rainfall < 60 mm, between 60 to 100 mm, and > 100 mm.

TABLE 2. Division of clusters and categories of wet, humid, and dry months

	Wet Month	Humid Month	Dry Month
Cluster I			
Anjatan, Bugel, TL Kacang, Kr.Asem, LW Semut, Wanguk, GBWetan, Cikedung, Kroya, Sukadana, Smr Watu, Tugu, Bondan, Tamiyang	Jan-April, Nov-Dec		May-Oct
Cluster II			
SL Darma, Gantar	Jan-April, Oct-Dec		May-Sept
Cluster III			
Cidempet, Losarang, Bangkir, Indramayu Jatibarang, Juntinyuat, Ked Bunder, Lohbener, Sudi Mampir, Krangkeng, SudiKamp	Jan-April, Nov-Dec	May-June	July-Oct

CONCLUSION

Data plots are carried out to compare groups of 3 patterns in profile analysis visually, namely, profile alignment, coincide, and alignment with the flat axis, which are validated using Hotelling's T-squared statistical test. Furthermore, there are several advantages associated with the t-test. For instance, the type I error rate is adequately controlled, with the relationship between multiple variables taken into account to generate an overall conclusion despite the inconsistency of multiple (single) t-tests. In conclusion, Hotelling's T-square statistical is used to summarize a t-test show variable differences between groups.

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