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A Concept of Kagan-Rodda Modification Due to the Distance among the Rainfall Stations

[1]Eri Prawati, [2]Suhardjono, [3]Lily Montarcih Limantara, [4]Rispiningtati

[1]Doctoral Program on Department of Water Resources, Faculty of Engineering, University of Brawijaya, Malang, East Java of Indonesia
[2, 3,4]Department of Water Resources, Faculty of Engineering, University of Brawijaya, Malang, East Java of Indonesia

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ABSTRACT

This study intended to develop a modification concept on Kagan Rodda method for analysis the distribution pattern of rainfall stations (n). In depth analysis, this modification was due to the distance (L) among the rainfall stations. Location of study was in some watersheds of East Java, Indonesia. Kagan-Rodda was well-known for analysis the distribution pattern of rainfall stations, however it was necessary to be modificated for applying in Indonesia. The methodology consisted of three development concepts as follows: 1) by using daily or monthly rainfall; 2) modification Kagan-Rodda formula of L = 3,89+0,96 √A/n; and 3) watershed was as real field condition in order to produce a new formula of Prawati-ub with the control model was observed hydrograph. Result can be used as the recommended formula for analysis on rainfall stations distribution pattern which is used as the base of water resources system planning.
KEYWORDS: rainfall stations distribution pattern, distance among the stations, kagan-rodda

INTRODUCTION

Analysis of rainfall is very necessary for hydraulic structure design. Errors in monitoring hydrological basis data are usually caused by inadequate quantity and uneven distribution pattern of rainfall stations in the watershed (Harto, 1988). Representative rainfall was analysis by selecting available scheme pattern of rainfall station. Information of rainfall condition in a watershed can be recorded by installing rainfall measurement equipments, that perform a rainfall observed network in the watershed. This network is hoped to be able to present data which can illustrates rainfall condition in the watershed. It is related with the distribution size and rainfall stations density in a watershed which can give the representative data of the watershed (Limantara, 2010). In addition, it is needed for knowing how big the distribution and density is influencing the error of data averaged value. Up to now, the problem on quantity and distribution of rainfall stations in Indonesia got no more attention. It was proved by there was no manual guide about what suitable method could be used for placing pattern and distributing the rainfall stations. Determination of rainfall stations network is not only restricted on the analysis of stations quantity that is needed in a watershed, but the place and distribution pattern are very important too. Qualitative guide was presented by Rodda (1972) such as by using the correlation coefficient of rainfall.

The previous researchs that were related with the determination on suitable quantity and distribution pattern of rainfall stations for hydrological analysis in a watershed have more been carried out due to the various methods. However, all of them were naccessary to be further evaluated for applying in Indonesia mainly in Java Island. Each of method needs the demand on quantity and quality of different data, so it had to be justified with the region where the research has been conducted. (Harto, 1987) has conducted the study in tropic region for a watershed with area number was smaller than 100 km^2 as well as bigger than 100 km^2. He expressed that the use of 10 units of rainfall stations were assumed to be suitable. In addition, it was also suggested to be used 15 units of rainfall stations in a watershed and it was expressed sufficient without paying attention to the area number.

Rodda (1976) conducted the research on determination of rainfall stations network not only limited on the quantity of needed rainfall stations in a watershed but it related to the place and distribution pattern. Distribution pattern and density of rainfall stations have big influence to the accuracy of rainfall estimation in a watershed. However, there has not been a commitment about the rule on determination of profitable rainfall stations and it was very felt mainly in tropical region like Indonesia. The practical problem which has not been solved was the selection on quantity and location of rainfall stations in a watershed for analysis interest that can give the result with the accuracy as high as possible (Prasetyorini, 2011). Although there has not especially carried out the evaluation, but Kagan-Rodda method has widely used for determining rainfall stations network in some watersheds of Java Island. However, there were the weakness of Kagan-Rodda as follow: 1) Kagan-Rodda method only analyzed daily and monthly rainfall and it has not been tried for yearly rainfall; 2) Kagan-Rodda

***Corresponding Author:** Eri Prawati, Doctoral Program on Department of Water Resources, Faculty of Engineering, University of Brawijaya, Malang, East Java of Indonesia. Email: eri.prawati@yahoo.co,id; lilymont@ub.ac.id

method used the formula of $L = 1{,}07\sqrt{\frac{A}{n}}$ for determining the distance among rainfall stations; 3) Kagan-Rodda method assumed that watershed was plain.

The development of rainfall distribution pattern in each country will never the same because the base criteria which is used is different. Up to now, there has not been seen the clear criteria and general using for determining the observation network density of a region. More over the using in Indonesia needs the accuracy because there are any problems that have not been described. It is due to hydrological condition in Indonesia is very different with the placed condition where the previous theory has been developed. In previous researchs, there were assumed that the surface depth of watershed was plain and it was as the reason to be studied that the surface depth of watershed was really not plain. In further analysis, the surface depth was as the averaged depth of a watershed from upstream to downstream.

MATERIALS AND METHODS

Objective of this study was to produce the new method on distribution pattern and density of rainfall station which was suitable with the condition in East Java region. Research location which was selected in this study was based on the consideration on the region with the topography variation of mountain range and plain for differentiating the optimum quantity of rainfall stations for each region. Optional watershed included Kedunglarangan, Rejoso, Blambangan, Kemuning, Sarokah, and Widas. Map of location was as in Figure 1.

Figure 1. Map of location
(Source: Water Resources Dinas of East Java Province)

Data using in this study primary and secondary data which were included as follow: 1) topography map with the scale of 1 : 25.000; 2) Rainfall data from Automatic Rainfall Recorder (ARR) on 6 watersheds for last 20 years; and 3) Discharge data from Automatic Water Level Recorder (AWLR) on the weir for last 10 years. And some data of rainfall station such as the position of rainfall station and polygon of Thiessen, the distance among stations, and the number area of influenced area based on polygon of Thiessen.

Modification concept of Kagan-Rodda method on placing the rainfall distribution pattern (n) and the distance among stations (L) in smoe watersheds of East Java province was carried out by studying the weakness of Kagan-Rodda method for applying in Indonesia watersheds and then comparing it with the new concept by developing the weakness of Kagan-Rodda Formula. Based on the available literature study, there were some weakness of Kagan-Rodda method which described as in Table 1 below.

Table 1 The weakness of Kagan-Rodda Method based on literature study

No.	Method of Kagan-Rodda	Note
1.	Daily and monthly rainfall data	Not used yearly rainfall data
2.	Parameters of statistic: X , S , Cv The formula for determining the distribution distance and density of rainfall station pattern : L = 1,07 √A/n	The other formula of L: L = 3,89+0,96 √A/n
3.	Topography was assumed plain	Not always suitable for Indonesia where there were mountain range anywhere

There are some methods for analysis design rainfall such as Log Normal, Log Pearson Type III, and Gumbel. This study used the method of Log Pearson Type III because this method is flexible for any kind data distribution due to the statistical parameters such as follow:

$$r(d) = r(o).e^{\left(-\frac{d}{do}\right)}$$

$$Z1 = Cv.\sqrt{\frac{1 - r(0) + \left(\frac{0{,}23\sqrt{A}}{d(0)\sqrt{n}}\right)}{n}}$$

$$Z2 = Cv.\frac{1}{3}\left(1 - r(0) + \frac{0{,}52.r(0).\sqrt{\frac{A}{n}}}{d(0)}\right)$$

$$L = 1{,}07\sqrt{\frac{A}{n}}$$

note :

$r_{(d)}$	=	correlation coefficient for the station as far as the distance d
$r_{(o)}$	=	correlation coefficient for distance is very close to the station
C_v	=	coefficient variations
$d_{(o)}$	=	correlation radius for the distance between the station where the correlation is reduced by a factor of e
A	=	watershed area (km^2)
n	=	number of stations
Z1	=	alignment error (%)
Z2	=	interpolation error (%)
d	=	distances between stations (km)

RESULTS AND DISCUSSION

Analysis on the weakness of Kagan-Rodda

Evaluation method of Kagan-Rodda indicated besides the needed quantity of rainfall stations with certain error, it also showed the location or distribution of rainfall stations clearly in watershed. Research of Kagan-Rodda was conducted in England where the hydrological condition was very different with Indonesia. Kagan-Rodda has some weakness due to the development of rainfall distribution pattern (n) and the distance among stations (L) in watershed as described in Figure 2.

This research intended to modified the formula of $L = 3{,}89+0{,}96\ \sqrt{A}/n$ due to the slope factor of watershed. In addition, this study will try to use neither daily and monthly rainfall nor yearly rainfall and it is hoped to get the different coefficient of variance (Cv). Kagan-Rodda method presented the coefficient of variance between 0.30 and 0.60 by analysis the daily and monthly rainfall.

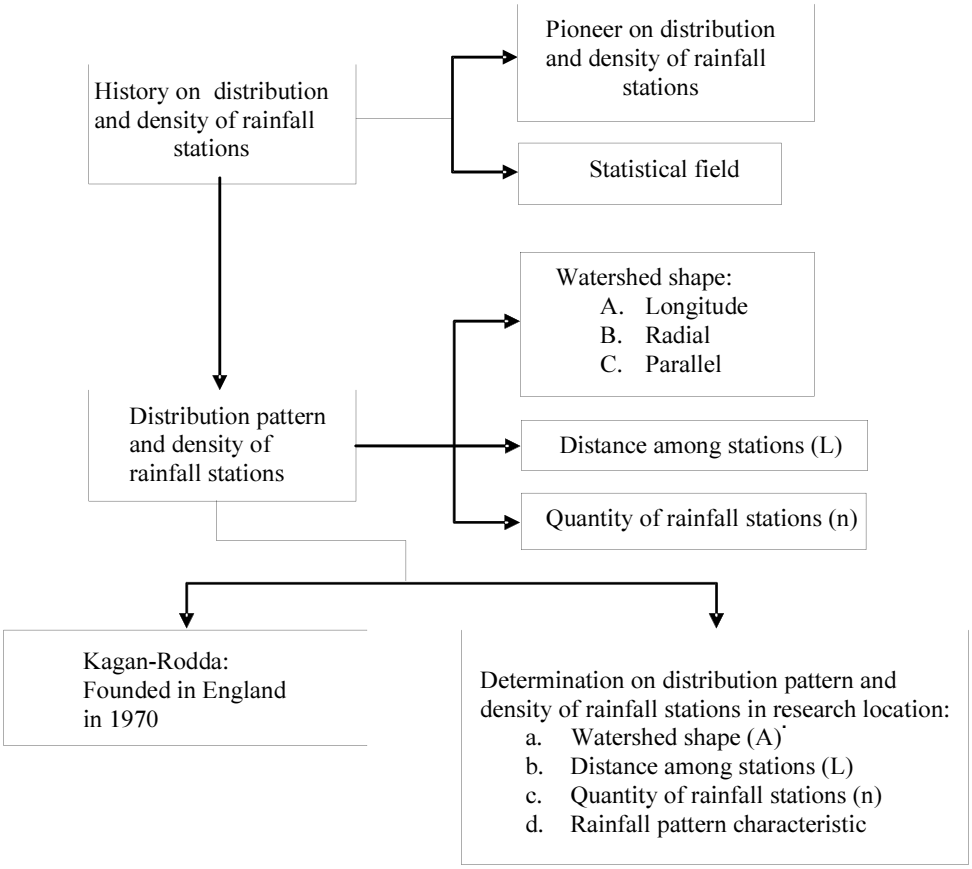

Figure 2 Concept map of research background

Analysis on the development of Kagan-Rodda method

By knowing the weakness of Kagan-Rodda method, it is built the new concept on arranging the new method which is more accurate and better. Design of new concept is presented as in Table 2.

Table 2 New method development concept of Prawati-ub

No.	Method of Kagan-Rodda	Method of Prawati-ub
1.	Daily/ monthly rainfall	Daily/ yearly rainfall
2.	Statistical parameters: X , S , Cv Formula on determination of distribution distance and density of rainfall stations: L = 1,07 √A/n	Statistical parameters: X , S , Cv Formula on determination of distribution distance and density of rainfall stations: L = 3,89 + 0,96 √A/n (Indonesia specialty)
3.	Plain topography	Topography due to field condition

Source: analysis result of research

CONCLUSION

The conclusion of this research was by knowing the weakness of Kagan-Rodda method, there can be developed the new formula of Prawati-ub by using: 1) daily or monthly rainfall data; 2) statistical parameters of X, S, Cv, the equation for determining the distribution distance and pattern density of rainfall station and the formula will become: L = 3,89+0,96 √A/n which is specialty for Indonesia; and 3) there is suitable with field condition).

REFERENCES

Harto BR, Sri. 1987. *Pengaruh Kerapatan Jaringan Stasiun Hujan Terhadap Ketelitian Perkiraan Hujan Rata-rata*. Proceeding Seminar Tinjauan Sistem Hidrologi dan Hidrolika, PAU, UGM.

Harto BR, Sri, 1988. *Optimasi Kerapatan Jaringan Stasiun Hidrologi* Yogyakarta: PAU Ilmu Teknik UGM.

Limantara, Lily Montarcih. 2010. *Hidrologi Praktis*. CV Lubuk Agung, Bandung, Indonesia.

Prasetijo, Hari; Limantara, Lily Montarcih; and Prasetyorini, Linda. 2011. Analysis of Average Rainfall Using Kagan-Rodda. *Journal of Applied Sciences Research*, 7(3): 309-313

Prasetyorini, Linda and Limantara, Lily Montarcih. 2011. Analysis of Design Flood Due to Rainfall Station Distribution. *Journal of Applied Sciences Research*, 7(6): 844-848

Rodda, J.C., Richard A., Downing, Frank, M. Law. 1976. *System Hydrology*. London-Boston: Newnes-Buterworths

Rodda, J.C., 1972, *Planning the Spatial Distribution of Hydro meteorological Stations to Meet an Error Criterion*, Casebook on Hydrological Network Design Practice, WMO-NO 324, Geneva.

Suhartanto, Ery and Haribowo, Riyanto. 2011. Application of Kagan-Rodda Method for Rain Station Density in Barito Basin Area of South Kalimantan, Indonesia. *Journal of Applied Technology in Environmental Sanitation*, 1(4): 329-334

World Meteorological Organization, 1981, *Guide to Hydrological Practices,* 4 th edition, WMO no 168, Genewa Switzerland