RESEARCH PAPER | GEOGRAPHY | Volume : 6 | Issue : 1 | JANUARY 2016 | ISSN - 2249-555X

Designing An Optimum Rain Gauge Network for Estimating Mean Rainfall in Dindigul District, Tamil Nadu

KEYWORDS: Rain gauge network, Mean annual rainfall, Isohyetal method

A. SENTHILVELAN

Assistant Professor, Department of Geography, Government Arts College (Autonomous), Kumbakonam – 612001.

ABSTRACT *Rainfall data provide a basis for various investigations pertaining to hydrology. As the spatial distribution of rainfall varies from one region to another, a good network of representative rain gauge stations to record the spatial pattern of rainfall is of utmost necessity. In this paper, an attempt has been made to estimate the optimum number of rain gauges required in Dindigul district.*

1. INTRODUCTION

Rainfall data provide essential input for effective planning, designing, operating and managing of water resources projects. Rainfall data are employed in various water resources management tasks such as water budget analysis and assessment, flood frequency analysis and forecasting, stream flow estimation, and design of hydraulic structures. A reliable rain gauge network can provide immediate and precise rainfall data that are crucial effective and economic design of hydraulic structures for flood control. This helps to minimize the hydrological and economic risk involved in different water resources projects. Rain gauge networks are usually installed to facilitate the direct measurement of rainfall data that characterize the spatial and temporal variations of local rainfall patterns in a catchment. A rain gauge network should be denser than networks used to measure other meteorological elements (e.g. temperature), because the highly variable rainfall patterns and its spatial distribution cannot be represented effectively without having a network of enough spatial density (Pardo Iguzquiza, 1998). A well-designed rain gauge network thus should contain a sufficient number of rain gauges, which reflect the spatial and temporal variability of rainfall in a catchment (Yeh et al., 2011).

Hydrologists are often required to estimate areal average rainfall over the catchment and/or point rainfall at unsampled locations from observed sample measurements at neighbouring locations. This task can be accomplished accurately with an optimally designed rain gauge network of any hydrological study. However, the rain gauge network used in most of the hydrological studies are often sparse and thus incapable of providing adequate rainfall estimates necessary for effective hydrological analysis and design of water resources projects. Use of inaccurate rainfall data may result in significant design errors in the water resources projects, which may eventually result in the immeasurable loss of lives and property damages. Thus, identification and selection of the best network configuration having optimal number and locations of rain gauge station is the sole objective of the network design. Hence, the optimal rain gauge network should contain the number and locations of rain gauge stations in such a way that it can yield optimum rainfall information with minimum uncertainty and cost (Kassim and Kottegoda, 1991; basalirwa et al., 1993; Pardo-Iguzquiza, 1998). The density of gauges depends upon the basic purpose behind their installation. A relatively sparse network of stations may be sufficient for determining annual average rainfall over large areas of a vast terrain, whereas a dense network is required to determine the rainfall pattern in the area dominated by thunderstorms. In the more developed and densely populated countries, there have been fairly good networks of rainfall stations for 70 to 100 years. The densest networks have been established in areas where economy is affected by local variations in rainfall. Besides, the high density networks are established for studying the effect of rainfall on certain specialized characteristics such as run-off and soil erosion.

2. OBJECTIVES

The present study is aimed at designing an optimum rain gauge network for Dindigul District with the following objectives;

* To find out the mean annual rainfall using isohyetal method
* To estimate the optimum number of rain gauges in the study area.

3. STUDY AREA

Dindigul District is located between 10°05′ and 10°09′ North Latitude and 77°30′ and 78°20′ East Longitude (Figure 1). It is spread over an area of 6266.64 Sq. Km. Dindigul District comprises of three Revenue Divisions namely Dindigul, Palani and Kodaikanal. There are eight Taluks, fourteen Blocks, 358 Revenue villages, 24 Special Villages (Panchayat) and 306 Panchayat Villages found in the district. The normal annual rainfall over the district varies from about 700 mm. to about 1600 mm. It is minimum around Palani (709 mm) in the northwestern part and Vedasandur (732.4mm) in the northeastern part of the district. It gradually increases towards south and southwest and reaches a maximum around Kodaikanal (1606.8 mm) the district enjoys a tropical climate. The period from April to June is generally hot and dry. The weather is pleasant during the period from November to January. Usually mornings are more humid than afternoons. The relative humidity varies between 65 and 85% in the mornings while in the afternoon it varies between 40 and 70%. Semi and tropical monsoon type of climate is prevailing in the plains of the District. However upper Palani recorded low temperature and fairly heavy rainfall. In the plains the maximum and minimum temperature recorded are 37.5′C and 19.7′C in the hill stations 20.6′C and 7.7′C respectively. One of the special features of the district is the prevalence of three

Volume : 6 | Issue : 1 | JANUARY 2016 | ISSN - 2249-555X

distinct climates viz., Temperate, Subtropical and Tropical. No other districts in Tamilnadu State have such unique agro climatic zones within the same district.

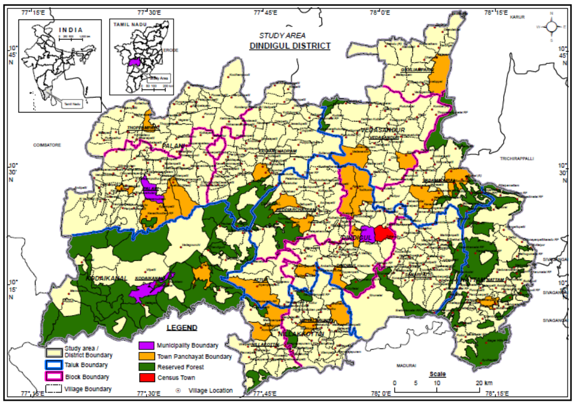

Figure 1: Location Map of the Study Area

4. METHODOLOGY

The daily rainfall data for the period of 34 years have been collected from Economics and Statistical Department, Chennai for the entire study area. The data have been converted into annual rainfall for preparing isohyetal map of the study area. An estimate of mean annual rainfall has been made for each zone between two successive isohyets.

The Indian Standards Institution (1994) has recommended a procedure for finding out the optimum number of rain gauges for estimating average rainfall in an area. Such estimation requires a set of rainfall data covering a considerable period in respect of each of the existing rain gauge station in the study area. In the present analysis, data on mean annual rainfall of 16 rain gauge stations in Dindigul District covering the period from 1980 to 2013 have been used. Using standard statistical procedure these data have been processed and the optimum number of rain gauges is estimated following the formula;

$N = (CV*100/P)^2$

where, N= Optimum number of rain gauge stations, CV = Coefficient of variation of the rainfall, P = Desired degree of percentage error in the estimate of mean rainfall.

5. RESULT AND DISCUSSION

The distribution of rain gauge network in and around the study area has been spatially

shown in figure 2. The Indian Standards Institution (1994) has recommended a procedure for finding out the optimum number of rain gauges for estimating average rainfall in an area. Such estimation requires a set of rainfall data covering a considerable period in respect of each of the existing rain gauge station in the study area. In the present analysis, data on mean annual rainfall of 16 rain gauge stations in Dindigul

District covering the period from 1980 to 2013 have been used. The mean annual rainfall of the study area has been shown in Table 1. The isohyetal map (figure 3) shows eleven isohyetal zones based on the area distribution pattern of rainfall of the study area. An estimate of mean annual rainfall made for each zone between two successive isohyets is shown in Table 2. The area enclosed in each zone is measured with the help of Arc GIS software and the respective mean annual rainfall is multiplied to obtain weighted mean rainfall for each zone. The mean annual rainfall for the study area is estimated to be 784.09 mm.

Table 1: Mean Annual Rainfall of Dindigul District (1980 – 2013)

Rain gauge Stations	Mean Annual Rainfall (mm)	Rain gauge Stations	Mean Annual Rainfall (mm)
Ayyalur	758.8	Nilakkotai	785.5
Berijam	878.0	Palani	700.6
Chatrapatti	723.3	Palar dam	701.6
Dindual	861.2	Palayam	483.1
Guijilamparai	558.1	Vadama-thurai	547.5
Kamatchipuram	711.5	Vedasandur	687.5
Kodaikanal	1421.7	Viralipatti	700.9
Natham	1000.9	Virupakshi	680.7

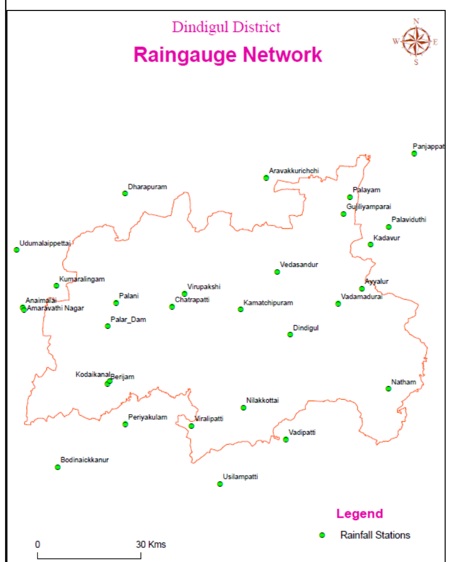

Figure 2: Rain gauge stations

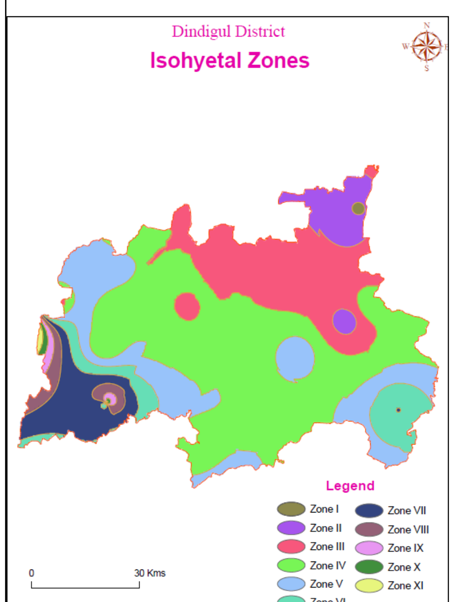

Figure 3: Isohyetal Map

Volume : 6 | Issue : 1 | JANUARY 2016 | ISSN - 2249-555X

Table 2: Estimation of mean annual rainfall in Dindigul District

Isohyetal Zones	Estimated Mean Rainfall between Isohyets (mm) $(\bar{x})$	Area between isohyets (Km²) (a)	$a(\bar{x})(\bar{x})$	$\bar{X} = \frac{\sum a(\bar{x})}{\sum a}$
I	491.5	9.29	4566.04	784.09
II	550.0	300.29	165159.50	
III	650.0	1149.94	747461.00	
IV	750.0	2576.35	1932262.50	
V	850.0	1027.13	873060.50	
VI	950.0	387.76	368372.00	
VII	1050.0	425.35	446617.50	
VIII	1150.0	114.13	131249.50	
IX	1250.0	31.90	39875.00	
X	1350.0	14.23	19210.50	
XI	1410.5	8.39	11834.10	
Total	**10451.75**	**6044.76**	**4739668.13**	

5.1. Estimating Optimum Rain gauge Network

The study area has a network of 16 rain gauge stations at present. All the rain gauges are of non-recording type. The calculation of co-efficient of variation (CV) initially involves the estimation of standard deviation and mean which are worked out to be 217.38 and 762.54 respectively from the data set presented in Table 3. The co-efficient of variation is calculated as 0.285 making using of the values of standard deviation and mean. Considering P as the error level at 5 per cent, the study area needs an optimum network of 32 rain gauge stations for a reliable estimate of its mean annual rainfall. The 32 rain gauge stations are then distributed in the isohyetal zones of the study area as per standard norms stipulated by Indian Standards Institution. The optimum distribution of rain gauge stations in each isohyetal zone is shown Table 3. On the basis of the area enclosed, the isohyetal zones II, III, IV, V, VI, VII and VIII require 2, 3, 14, 5, 2, 2 and 1 rain gauge stations respectively.

Table 3: Optimum Distribution of Rain gauge Stations

Isohyetal Zones	Area enclosed between isohyets (Km²)	Proportionate Area	Required Rain gauge Stations
I	9.29	0.15	0.05 = Nil
II	300.29	4.97	1.59 = 2
III	1149.94	19.02	6.09 = 6
IV	2576.35	42.62	13.64 = 14
V	1027.13	16.99	5.44 = 5
VI	387.76	6.41	2.05 = 2
VII	425.35	7.04	2.25 = 2
VIII	114.13	1.89	0.60 = 1
IX	31.90	0.53	0.17 = Nil
X	14.23	0.24	0.08 = Nil
XI	8.39	0.14	0.04 = Nil

5.2. Existing and Additional Rain gauge Stations

The pattern of distribution of existing and proposed number of rain gauge stations in different isohyetal zones is shown in Table 4. As evident from the table, the additional number of rain gauge stations that need to be installed in the study area is then found comparing the existing number with the optimum number of rain gauge stations. The isohyetal zones I, IX, X and XI require no additional rain gauges as they already have rain gauges that equal or exceed the optimum number of estimated for them. The total number of rain gauge stations covering both the existing and proposed stations in the study area will be 34 instead of 32 as the zones I and XI possess one existing rain gauge each against no rain gauges are required in the zones as per the analysis.

Table 4: Existing and Additional Rain gauges in Isohyetal Zones

Isohyetal Zones	Optimum Rain gauge Stations	Existing Rain gauges	Additional Required	Existing and Additional Rain gauges
I	0	1	0	1
II	2	2	0	2
III	6	2	4	6
IV	14	7	7	14
V	5	2	3	5
VI	2	0	2	2
VII	2	1	1	2
VIII	1	0	1	1
IX	0	0	0	0
X	0	0	0	0
XI	0	1	0	1
Total	**32**	**16**	**18**	**34**

6. CONCLUSION

From the present analysis, the following conclusions emerge out;

* The mean annual rainfall for the study area is estimated to be 784.09 mm using isohyetal method.
* The study area needs an optimum network of 34 rain gauge stations against the existing 16 for a reliable estimate of its mean annual rainfall.
* The isohyetal zones II, III, IV, V, VI, VII and VIII require 2, 3, 14, 5, 2, 2 and 1 rain gauge stations respectively.

REFERENCE 1. Aksara Putthividhya and Kenji Tanaka, (2013), "Optimal Rain Gauge Network Design and Spatial Precipitation Mapping Based on Geostatistical Analysis from Co-located Elevation and Humidity Data", chiang Mai J. Sci.,40(2), 187-197. 2. Chow, V.T.,(1976), " Hydrology In Asian Cilizations", Water International, 7-10. 3. Chow,T.V.,(1964), " Handbook of Applied Hydrology", McGraw- Hill Book Company, Newyork. 4. Dhar, Rakhenha and Mandal,B.N.,(1981), "Some factors about Indian rainfall-A Brief Appraisal From Hydrologic Consideration", Indian Journal of Power and River Valley Development, 7/8, 117-125. 5. East Bora, A.K., and Goswami, D.C., "Designing An Optimum Rain Gauge Network For Estimating Basin Mean Rainfall In The Dhansiri Basin, North India", Geographical Review Of India, 55, 18-24. 6. Garg, S.J.M.,(1987), "Hydrology And Wapany", Resource Engineering, Khanna Publishers,185. 7. Indian Standards Institution, (1994), "Recommendations For Establishing Network of Rain-Gauge Stations", Publication, 15, 4987. 8. Mutreja, K.N.,(1986), "Applied Hydrology", McGraw Hill Book Company, New Delhi, 958. 9. Rao,K.I.,(1975), "India's Water Wealth", Orient Longman, New Delhi. 10. Sajal Kumar Adhikary and et. al., 2014, "Optimal design of rain gauge network in the Middle Yarra River Catchment, Australia", Hydrological Processes. 11. W.M.O.,(2008), "Guide To Hydrological Practices", W.M.O, 168, 82.