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Investigation of Influence of Terrain on Rainfall for Vembanad Basin, Kerala, India

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Abstract: Hydrological modelling, which helps in irrigation planning, water resources development or inundation studies, requires precipitation as a primary input. As the output of the rainfall-runoff model is used for water budgeting during a water resources planning or management, misestimation of rainfall should be avoided. There are various factors, such as topography, which dictate the variation of precipitation from place to place mostly in mountainous regions. The present study investigate the influence of topography on rainfall in a portion of Kerala, which is bounded by the Western Ghats ranges on one side and the sea on other side. Daily rainfall series data for 33 stations have been analyzed to find patterns in spatial distribution using preparation of isohyets for annual rainfall values and a regression analysis was calculated between annual rainfall values and station elevation. The study showed that there is similar pattern of isohyetal contours between 2001 and 2003; 2002, 2007 and 2008; 2005 and 2006. However, the dependence of average annual rainfall on elevation of station was found to be very weak with a maximum correlation coefficient of 0.1147 by an overall study. The results concluded that there is no clear relation between elevation and precipitation for the study area. Apart from rainfall, other factors such as aspect, orientation of wind with respect to hill slope, slope, etc. may aid in arriving at better elevation-precipitation relationship.

Keywords: *Rainfall, Western Ghats, Vembanad, Orographic, Regression analysis, Kerala and Altitude*

1. Introduction

Precipitation is one of the vital meteorological inputs required in hydrological modelling. For hydrological studies, precipitation data recorded from a network of gauges installed in the study area are chosen and given as input for accounting the spatial variability of rainfall or snowfall. In advanced mechanism, with the support of Doppler radars, it is possible to get a much better measure of the spatial variation of rainfall. However, currently, many river basins only have sparse rain gauges, let alone radar based gauges. Moreover, the number of rain gauges in the hilly regions is still lesser. Therefore, in hydrological studies such as modelling, various methods of interpolation and extrapolation are used in case there is limited number of rain gauges in a study area [2].

While assessing water availability of a basin through rainfall-runoff modelling, rainfall is a key input, and hence its misestimation can result in erroneous water budgeting during a water resources planning exercise or in modelling-based resources management. Therefore, it is important to rightly choose the method of interpolation or extrapolation, especially in case of sparse data availability. In practice, a network of precipitation measurements can be converted to areal estimates using any of a number of techniques such as the following: Arithmetic mean, Isohyetal analysis, Thiessen polygon, Distance weighted technique, etc. However, it is difficult to ascertain the suitability of any interpolation method for a region. It is known that rainfall always does not have a homogeneous spatial distribution over the earth surface. There are many factors, which dictate the variation of precipitation from place to place. Topography, especially, plays a great role in determining the spread and distribution of a storm. In mountainous regions, there is evidence and reason to believe that, due to orographic effect increased precipitation is experienced with increase in elevation [1] [5]. The effect of altitude on precipitation has been investigated in studies as old as [4].

The present study is aimed at investigating the influence of topography on rainfall in a portion of Kerala (Figure 1), which is bounded by the Western Ghats ranges on one side and the sea on other side. Such a study will imply whether to account the topographic variation while estimating basin-wide rainfall variation through spatial interpolation and/or extrapolation, and therefore, assist in hydrological modelling.

2. Study Area

The study area lies in the southern state of India, Kerala, and is bounded by the latitudes 9°5’2’’N and 9°56’10’’N, and longitudes 76°19’19’’E and 77°11’24’’E. On the western side is the Arabian Sea coast, and on the eastern side the area is bound by the Western Ghats. The minimum altitude in the lowland area is 2.2 m below mean sea level (msl), whereas the maximum altitude in the Western Ghats is nearly 2629 m above msl. The districts covered by the five river basins are Ernakulam, Kottayam, Alappuzha and

Pathanamthitta. The area is about 35% agricultural land. The prominent cultivation in the study area are rice, coconut, tapioca, arecanut and banana. Table 1 provides details of the land use/cover percentage distribution.

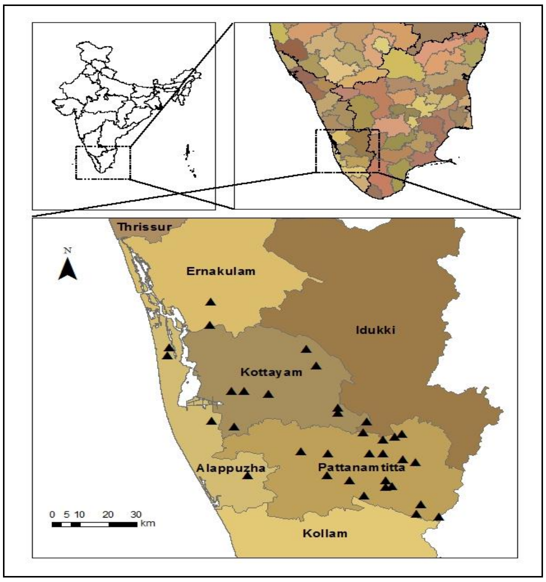

Figure 1 *Location of Rain gauges*

Table 1: *Land use/cover of the study area*

Sl. No.	Land use/Cover	Percentage
1	Forest	29.39
2	Agriculture	34.82
3	Built up	3.51
4	Barren land	3.28
5	Water and Wetland	29.00

The area receives an annual rainfall of 3400 mm, with an inter-locational variation from nearly 2500 mm at one location to 5300 mm at other location. The area contains mainly five river basins Muvattupuzha, Meenachil, Manimala, Pamba and Achenkovil, set by five west flowing rivers which originate in the hills of Western Ghats. Being fed by rainfall alone, the rivers have negligible or low flow during a part of the year. Meenachil, Manimala and Achenkovil rivers have almost no flow in non-monsoon season, whereas Pamba and Muvattupuzha rivers have significant flow, respectively, due to upstream reservoir storage in Pamba basin and contribution from Idukki reservoir release to Muvattupuzha River [3].

These rivers contribute to the Vembanad Lake which lies in the southern half of the state and drains into the Arabian Sea. The region adjoining the lake is called Kuttanad and is of specific agricultural importance. This region is also called the rice bowl of Kerala and produces a major part of the rice yield of the state. The Kuttanad area consists of the major part of district Alapuzha, some part of Kottayam and minor parts of Patanamthitta and Ernakulam. The Kuttanad region also faces the problem of floods quite frequently [6].

3. Materials and Methodology

Daily rainfall series data received from Irrigation Design and Research Board (IDRB), Water Resources Department, Govt. of Kerala were used in this study. Eight years of data, for the years 2001-08, for 33 stations have been analyzed to find patterns in spatial distribution using preparation of isohyets for annual rainfall values. The isohyets plotted with the elevation in background gives an initial idea of rainfall pattern.

Next, a regression analysis was done between annual rainfall values and station elevation to find dependence of altitude on rainfall values.

Table 2: *Distribution of rainfall station in bands*

Elevation Bands	Number of Rainfall Stations
0-50 m	13
51-100m	4
101-150m	4
151-200m	3
201-250m	1
251-300m	1
301-350m	1
351-400m	1
401-450m	4
501-550m	1
800-850m	1

In the third step, the rainfall stations were grouped into bands, each of 50 meter elevation as class interval. Table 2 shows the grouping of rainfall stations. The average annual precipitation of these groups of stations were calculated and checked for any visible trend dependency related to elevation.

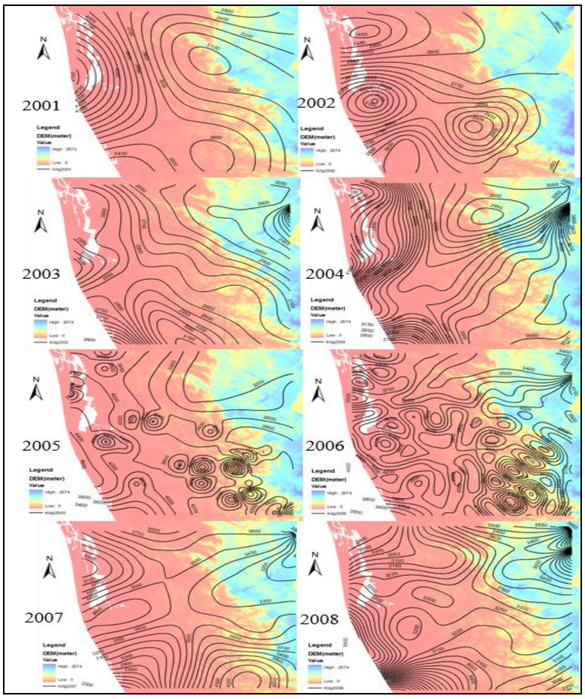

Figure 2 *Isohyets for Years 2001-08*

4. Results and Discussion

The isohyetal maps for the years 2001-08 are shown in Figure 2. The digital elevation map has been used in background for all the 8 plots in order to indicate the variation in altitude or in other words, the terrain profile. Similar pattern of isohyetal contours are observed between (i) year 2001 and year 2003; (ii) year 2002, year 2007 and year 2008; and (iii) year 2005 and year 2006. It is also seen that except for years 2005 and 2006, the contours have are formed parallel to changing terrain profile either towards the western boundary, which defines the coast, or in the mid region between east and western boundary where the terrain elevation experiences an increase. These observations partially show the influence of terrain on the rainfall distribution.

The second set of analysis uses scatter plots between annual rainfall values and the station elevation values. The results are presented in Figure 3. The coefficient of determination (R^2) for the years 2001-08 are as in Table 3. The dependence of average annual rainfall on station elevation is found to be very weak, as indicated by a maximum R^2 value of 0.1147 found through regression analysis.

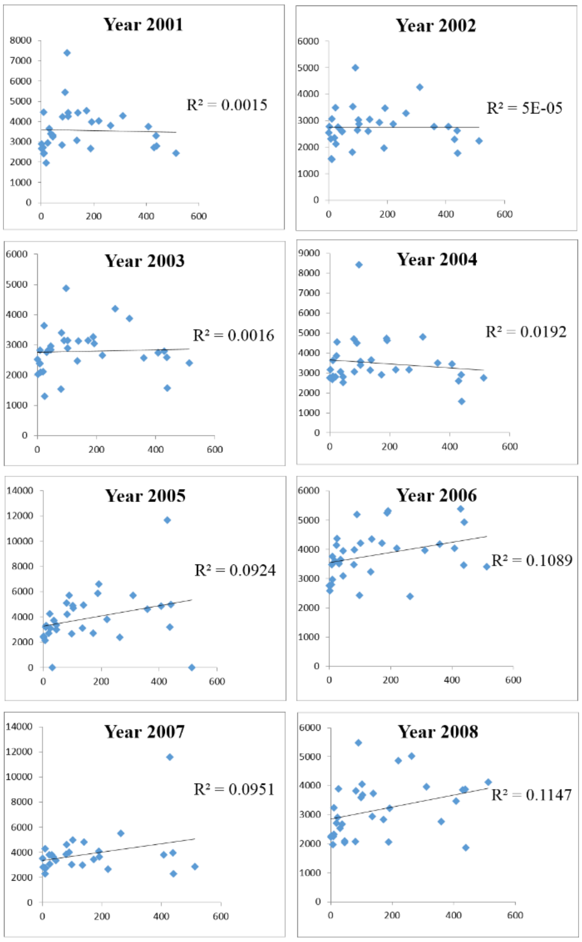

***Figure 3** Scatter plots between Rainfall (mm) on x-axis and Altitude (m above msl) on y-axis for Years 2001-08*

***Table 3:** Distribution of rainfall station in bands*

Sl.No.	Year	R^2
1	2001	0.0015
2	2002	0.00005
3	2003	0.0016
4	2004	0.0192
5	2005	0.0924
6	2006	0.1089
7	2007	0.0951
8	2008	0.1147

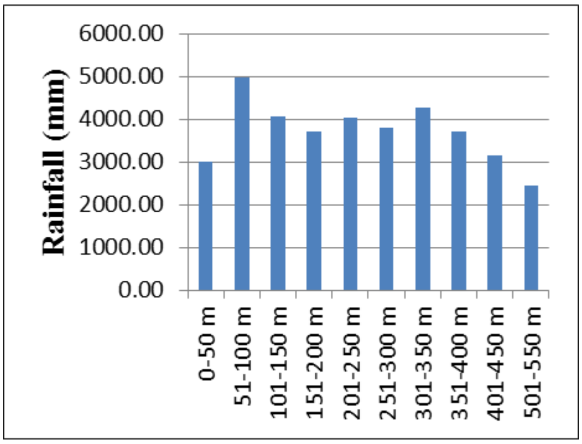

***Figure 4** Band-wise averaged annual rainfall 2001*

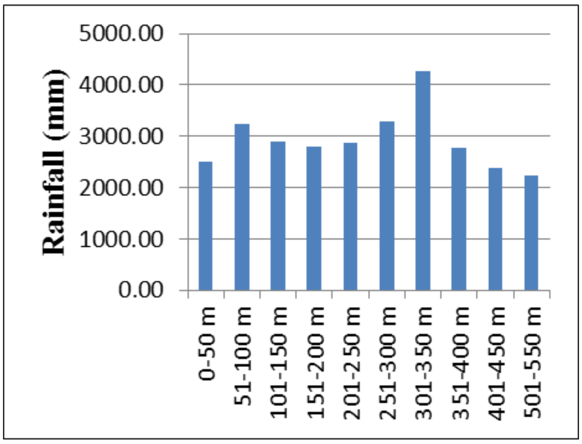

***Figure 5** Band-wise averaged annual rainfall 2002*

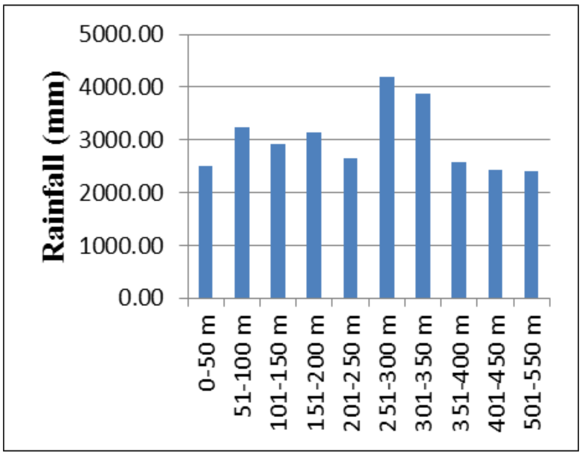

***Figure 6** Band-wise averaged annual rainfall 2003*

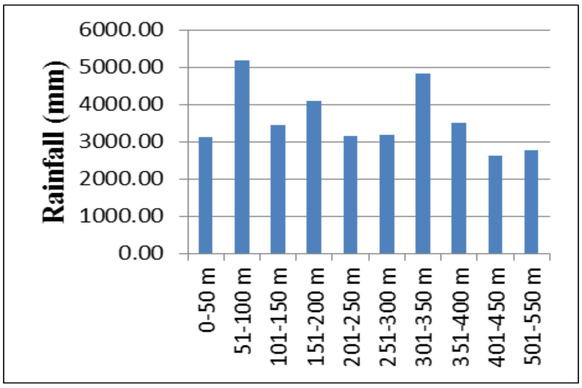

***Figure 7** Band-wise averaged annual rainfall 2004*

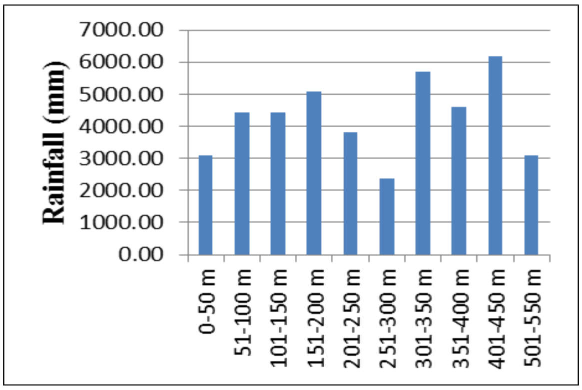

***Figure 8** Band-wise averaged annual rainfall 2005*

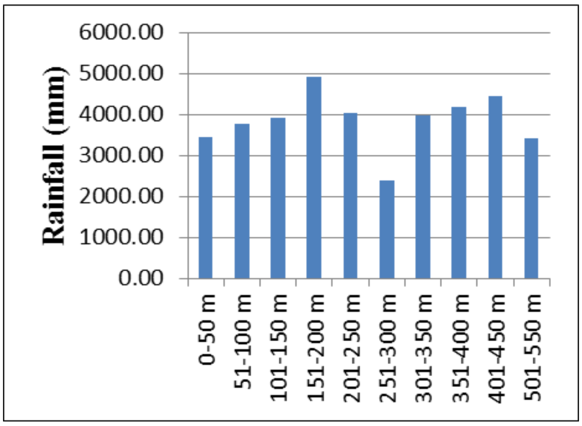

***Figure 9** Band-wise averaged annual rainfall 2006*

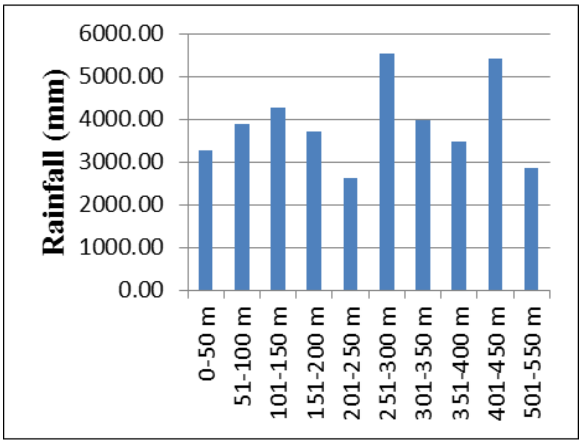

***Figure 10** Band-wise averaged annual rainfall 2007*

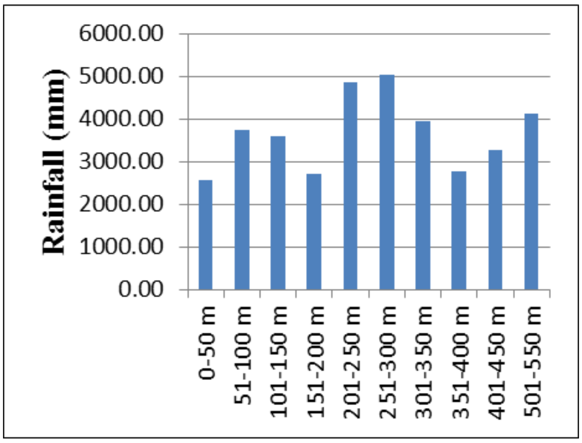

***Figure 11** Band-wise averaged annual rainfall 2008*

The third level of analysis uses elevation-band-wise averaged rainfall. The column corresponding to first band 0-50m indicates the average annual rainfall of all station in the corresponding elevation range. The number of stations in each band is as shown in Table 2. The Figures 4-11 show the plots for the eight years.

These figures further substantiate the inference from the earlier analyses that there is no perfect linear relationship between rainfall and station elevation. The similarity or constancy in pattern that is observed between these eight plots is that the bands of lowest and highest elevation have lower rainfall than their neighboring elevation bands.

5. Conclusion

The results show that there is no clear relation between elevation and precipitation for the study area. Including factors like aspect, orientation of wind with respect to hill slope, slope, etc. may aid in arriving at better elevation-precipitation relationship.

In general, the presently available software programs for hydrologic modelling make the use of some interpolation techniques to compute the rainfall as a continuous spatial input at all the points in the modelled region. The observed rainfall data at known points are used for this purpose as the basic input. Two of the widely used software tools for rainfall-runoff estimation are HEC-HMS (Hydrologic Engineering Center - Hydrologic Modeling System) and SWAT (Soil and Water Assessment Tool). The HEC-HMS model estimates precipitation in form of frequency storm, gage weights, gridded precipitation, inverse distance method, SCS storm, user-specified isohyet method and standard project storm. The SWAT model divides the modelled region into number of subbasins as desired by the user and assigns one rain gage station for each subbasin. This dominant rain gage station is chosen based on the Thiessen Polygon method. Although these models have the facility to incorporate changes in precipitation with respect to altitude (e.g.: PLAPS in SWAT model), there is scope of improvement with the integration of other factors like aspect, orientation, slope, etc. in better rainfall estimation, especially for hilly terrains.

5. Acknowledgements

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