Spatial Prediction of Rainfall using Universal Kriging Method: A Case Study of Mysuru District

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Abstract: **Rainfall is a key factor for determining the sustainability for conservation of living species on the earth. Rainfall is an unpredictable and random phenomenon in nature. The change in rainfall pattern and its impact on surface water resources is an important climatic problem faced by society today. However, rainfall is the most elusive and uncertain phenomenon to predict. Geostatistical methods are now commonly used to analyze spatial variability of random phenomenon. In recent years, kriging interpolation technique is gaining more frequent use for many applications, since it gives better prediction than regression methods. The objective of this study is to predict rainfall for Mysuru district using universal kriging interpolation method. Data from a total of 21 raingauge stations of Mysuru district have been used for interpolating rainfall for the years 1994, 1999, 2004, 2009 and 2014. The results indicated that the spatial variation of rainfall in 1994, 2004 and 2009 varies from moderate to very high level whereas in 1999 and in 2014 the rainfall varies from moderate to high level. Based on the comparison of predicted rainfall and the actual observed rainfall at few of the stations, the prevalent results from universal kriging interpolation method adopted in the present study have been found to be satisfactory and encouraging.**

Key words: Rainfall, Prediction, Interpolation, Geostatistics, Universal kriging.

I. INTRODUCTION

The need for water is increasing due to population growth, economic development, agricultural planning and urbanization. The amount of utilization of water for all these aspects depends on rainfall. Rainfall is a key factor for determining the sustainability and for conserving living species on the earth. Spatial and temporal variability of rainfall is due to natural internal process within the climate system or due to variations caused by human activities. The change in rainfall pattern and its impact on surface water resources is an important climatic problem faced by society today. The use of rainfall data is essential and fundamental for the rainfall- runoff process. Rainfall data of a particular area are analyzed using several methods. Many researchers have been using spatial statistics methods [1], [2], [3] and [4] to predict rainfall and its variation. Universal kriging interpolation method has been used in many studies [4] , [5] and [6] to interpolate rainfall and has been found that it is most suitable when compared to other deterministic methods. The details of different methods of kriging may be found in [7], [8]. The objective of the present study is to predict rainfall for Mysuru district in Karnataka state using Universal kriging.

II. STUDY AREA AND DATA USED

Mysuru is the third largest city in terms of population in the state of Karnataka, India. The total geographical area of Mysuru district is 6,241 Sq.km. The study area lies between the North latitudes 11° 44' N and 12° 37' N and East longitudes between 75° 57' E and 77° 12' E. The district is bound on the north by Mandya and part of Hassan districts and on the east by Chamarajanagar. Kodagu forms its western boundary and the southern portion is covered by Kerala and part of Chamarajanagar district. Figure 1 shows the location of study area. The climate of the district is moderate throughout the year, and the district gets rainfall during two seasons, namely, the southwest monsoon season or rainy season, which is between June to September and retreating monsoon season during October and November. The rainfall data from 25 rain gauge stations distributed across the study area has been used in the present study. Table 1 shows the details of rain gauge stations in the study area and their location.

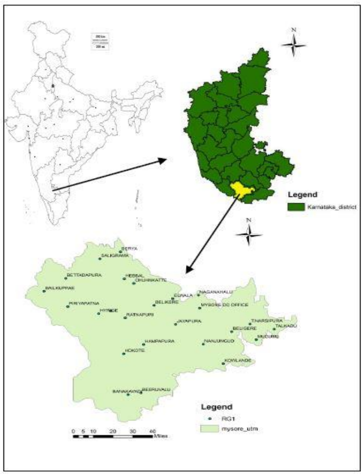

Figure 1: Location of study area

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Table 1: Rain gauge Stations along with their locations

Sl.no	Raingauge stations	Latitude N (Degree)	Longitude E (Degree)
1	H.D. kote	12.088	76.327
2	Bankavadi	11.866	76.300
3	Beervalu	11.947	76.462
4	Hampapura	12.121	76.475
5	Beechanahalli	11.986	76.351
6	Hunsur(trs)	12.31	76.289
7	Ratnapuri	12.227	76.320
8	**Hirige**	**12.221**	**76.204**
9	**Bherya**	**12.589**	**76.349**
10	**Chunchanakatte**	**12.502**	**76.293**
11	Saligrama	12.560	76.268
12	Hebbal	12.359	76.608
13	Mysuru city	12.309	76.640
14	Naganahalli	12.378	76.652
15	Elwala	12.343	76.583
16	Jayapura	12.204	76.553
17	Biligere	12.149	76.794
18	Kowlande	12.001	76.785
19	Bettadapura	12.471	76.104
20	Bailukuppa	12.40	75.981
21	T .Narasipura	12.21	76.899
22	Mugur	12.12	76.943
23	Talakadu	12.19	77.030
24	Piriyapatna	12.33	76.098
25	**Nanjanagud**	**12.11**	**76.680**

Out of these, data from 21 stations have been used for interpolation purpose and the data from the remaining four stations are used for testing the accuracy of prediction. The rain gauge stations used for testing the predicted values are highlighted in Table 1.

III. METHODOLOGY

The present study includes interpolation of rainfall data in the form of point rain gauge readings from 25 rain gauge stations spread across the study area. The point rain gauge data are handled using MS EXCEL spreadsheets in order to calculate yearly rainfall and other statistical parameters. The analysis has been carried out using Geographic information system (GIS).

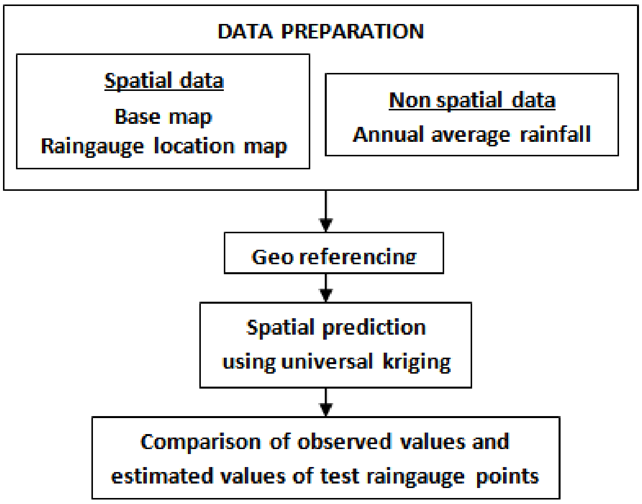

Figure 2: Flowchart indicating methodology

The overall methodology adopted in the present study is shown in Figure 2. The point rainfall data collected from the statistical department of Mysuru district has been analyzed and average annual rainfall has been computed. Base map showing the district boundary was digitized using toposheets. Layer showing the location of rain gauge stations was prepared in GIS platform.

IV. KRIGING INTERPOLATION METHOD

In kriging interpolation, the variable to be mapped is considered as a regionalized variable and by computing a semivariogram, the spatial autocorrelation of the data is modeled. Once the semivariogram model is known for the data set, it is possible to estimate the value of the variable at any unmeasured location.

The input data points (i.e. location data of raingauge stations and corresponding rainfall) are examined to construct a sample or experimental variogram which shows the degree of spatial autocorrelation as a function of distance between points. As the distance between points being compared is increased, the difference between them also increases. However, their differences become equal in value to the standard deviation after a certain distance and the semivariance no longer increases. The semivariogram becomes flat and the corresponding semivariance is called the sill. The distance at which this occurs is called the range of the regionalized variable. The range defines the region where the variable is spatially dependent. Another parameter of a variogram is the nugget, which is the variance at zero distance. Thus, the semi variogram model to be used plays an important role in kriging interpolation. Figure 3 shows a typical variogram for a random field with these parameters.

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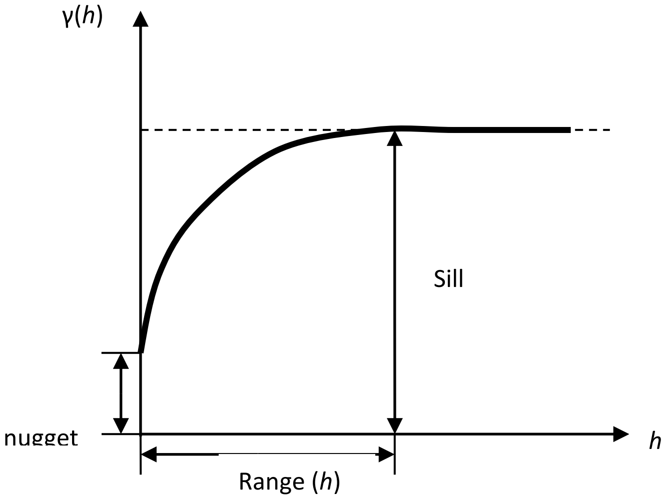

Figure 3: Typical variogram of a random field

Universal kriging

Universal kriging is applied when the mean (μ) is assumed to show a polynomial function of spatial coordinates [9]. Generally, the mean value for spatial data cannot be assumed constant, since it depends on the location of the sample. For this purpose, the spatial universal kriging is used which aims to predict z(x) at unsampled location. It splits the random function into a linear combination of deterministic functions, the smoothly varying and nonstationary trend, or also called drift, and a random component $Y(x) = (z(x) - \mu(x))$ representing the residual random function. In universal kriging more the number of sample data points used better the precision of universal kriging.

V. RESULTS AND DISCUSSION

Figure 3 shows the estimated spatial variation of rainfall categorized into four classes *viz., Low* (0-600*mm*), *Moderate* (600-800*mm*), *High* (800-1000*mm*) and *Very high* (1000-1500*mm*).The spatial variation of rainfall in 1994 varies from moderate to very high; In 1999 spatial variation of rainfall varies from moderate to high; in 2004 and 2009 spatial variation of rainfall varies from moderate to very high and spatial variation of rainfall of 2014 varies from moderate to high level. The prediction of year-wise spatial variations in rainfall shows that the study area has fluctuations in annual rainfall for the years 1994, 1999, 2004, 2009, 2014 which vary between slight and extreme rainfall.

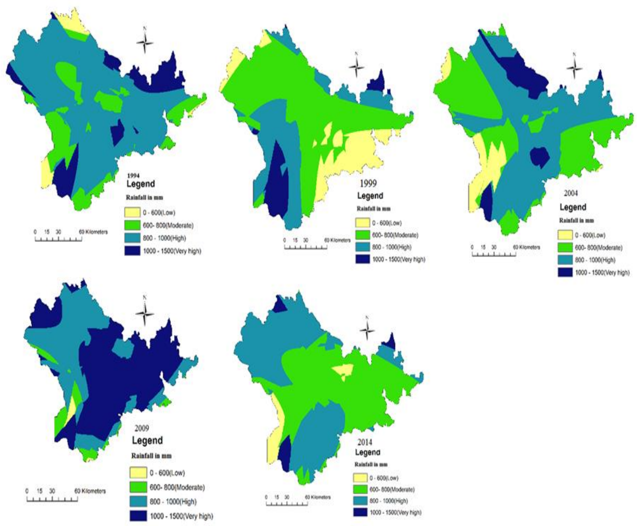

Figure 3: Spatial distribution of rainfall for the years 1994, 1999, 2004, 2009 and 2014

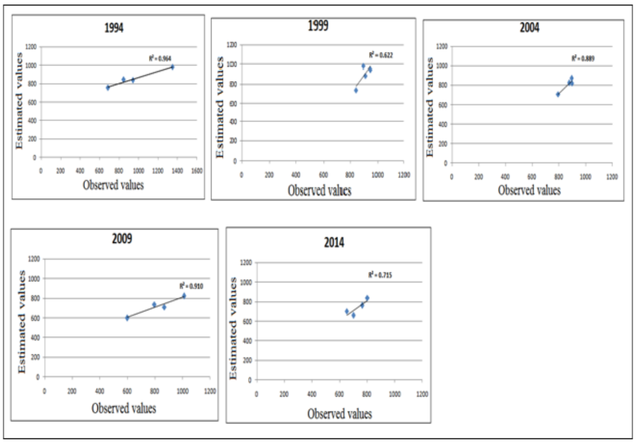

Figure 4: Estimated and observed values of rainfall for the years 1994, 1999, 2004, 2009 and 2014

Correlation coefficients are determined using estimated and observed values. The predicted R^2 value (figure 4) for the year 1994, 2004 and 2009 is near to one which is more reliable when compared to the 1999 and 2014. Higher the R^2 value, better the model fits the results.

The spatial distribution of rainfall (figure 3) in 1994, 2004 and 2009 varies from moderate to very high values and shows correlation of 0.964, 0.889 and 0.910 (figure 4) ; whereas the spatial distribution of rainfall in 1999 and 2014 (figure 3) varies from low to moderate values and the R^2 value shows correlation of 0.622 and 0.715 (figure 4). The number of data points used in this prediction is 21; the value of R^2 may vary due to dependency of spatial interpolation locations and also on the correctness of sample rainfall data points.

VI. CONCLUSIONS

Rainfall is the most elusive and uncertain phenomenon to predict. Geostatistical methods are now commonly used to analyze spatial variability of rainfall which is considered as a random phenomenon. In this study an attempt has been made to predict rainfall in Mysuru district with the use of geostatistical method such as universal kriging. The prevalent results from universal kriging were found to be satisfactory and encouraging. Further more studies are required with more number of data points and the accuracy may be scrutinized. When interpolating with very few neighbourhood sample points care should be taken owing to the fact that this method can extrapolate outside the range of data values and cause a poor results. The study reported here has made aware of the need for further work in order to find the ways and means to improve the accuracy of rainfall input for interpolation techniques.

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