International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

Estimation of drought characteristics in the state of Maharashtra

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Abstract: Drought is a recurring event in peninsular India and has large scale socio-economic impacts. In order to reduce the drought impacts, a continuous monitoring of drought characteristics is required. This study is aimed at estimating drought characteristic- mainly drought area and aerial deficit- in the state of Maharashtra. A large variation in the rainfall amount was observed across the state. It was found that central part of the state, being on the leeward side of Western Ghats, is the worst drought hit area. Apart from this, the eastern part of the state was also under considerable water stress. The results obtained from statistical analysis were converted to spatial domain using ordinary kriging, in order to demarcate zones of varying drought severity.

Index terms: Drought characteristics, Aerial deficit, Normalized deviation, Ordinary kriging

I. INTRODUCTION

The rising temperature of our planet is a matter of serious concern to the scientific community. Climate change and its after effects can be witnessed by each passing year. One such effect of increased global temperature is the frequent occurrence of droughts. Drought is an event of drier than normal rainfall, which has resulted in water scarcity issues in a region. It can have life threatening consequences in the long run if it is not monitored regularly.

The first occurrence of any drought event can be traced from the precipitation records. This is the reason that meteorological drought has been mainly dealt with in this work. This study makes use of the precipitation records in order to predict drought characteristics in the state of Maharashtra. The main drought characteristics studied are drought area and aerial deficit. Firstly, pure statistical averages were computed and then a detailed analysis was performed using normalized deviation index and ordinary kriging.

Maharashtra was chosen as the area of study because it is a part of the rain shadowed region of peninsular India and the rainfall variability is very large across the state. The state has witnessed frequent drought events in the past, and such was the severity of 2013 drought that the state administration had to run water trains in order to fulfil the basic water supply needs. This study is an attempt to identify worst affected drought areas in the state of Maharashtra and characterise them into different zones of severity.

II. SOURCE OF DATA

The rainfall data required to perform this study was taken from Indian Meteorological Department (IMD) under the project titled "Drought area mapping using geostatistical modelling approach" sponsored by Science and Engineering Board (SERB), Department of Science and Technology, Government of India. Monthly rainfall data for 41 stations across the state of Maharashtra for the time period of 1966 to 2016 was analysed. The rainfall stations along with their spatial locations is shown in figure 1. This map was prepared using ArcGIS 10.4.1.

III. METHODOLOGY

This study was performed in two halves. Firstly, statistical averages were calculated for the state. For this a whole to part approach was followed. Maharashtra is regionally divided into three regions. The westernmost coastal region is named as Konkan, the easternmost region from district Akola and onwards is Vidarbha and the central region is called Marathwada. So statistical averages were calculated for the data were calculated to identify critical zones. The results of this analysis are shown in table 1. Notably the average annual rainfall for Maharashtra state is 107.35 mm.

Table 1: Regional Analysis

Zone	Annual Average Rainfall
Konkan	192.2mm
Marathwada	54.4 mm
Vidarbha	84.71 mm

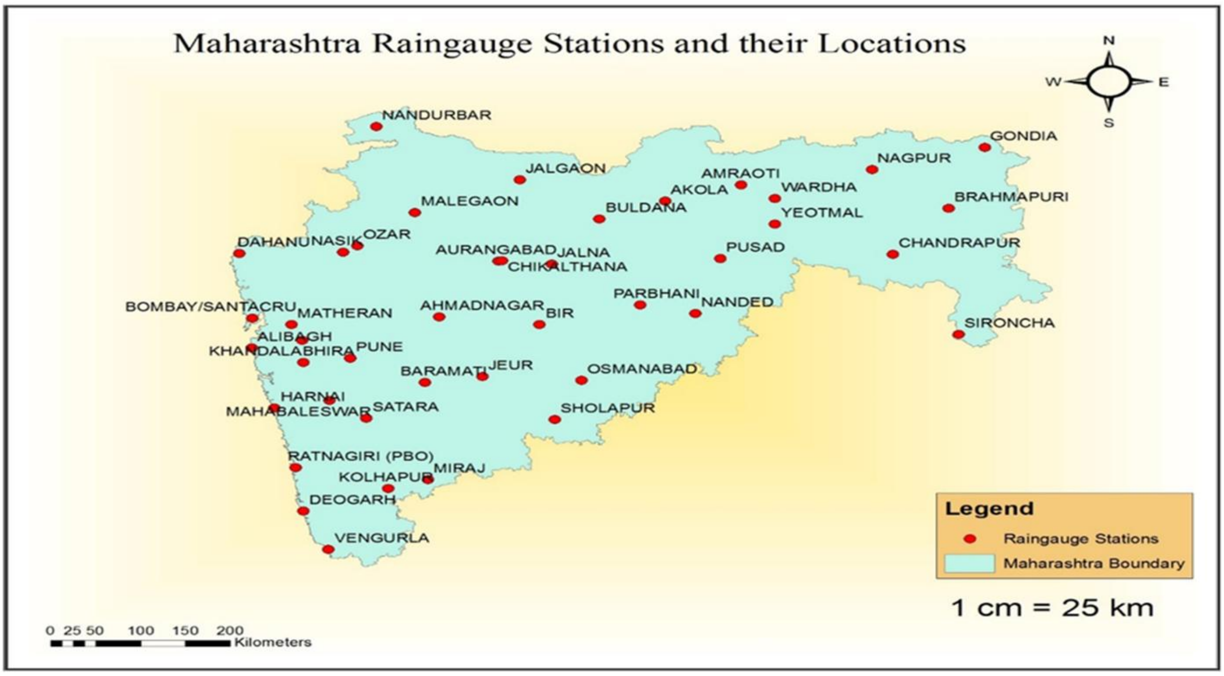

Figure 1: IMD Raingauge Stations and their locations.

The second part of this study makes use of Normalized deviation and Ordinary Kriging. This is a sort of confirmatory analysis of the previous study. Normalized deviation is a drought index which is used by Indian Meteorological Department to identify drought areas. The results so obtained were then plotted on the spatial domain using ordinary kriging. Ordinary kriging is a spatial interpolation technique, which helps to calculate values at points where data is not available. In this study, Kriging was used to make maps, delineating zones of varying drought severity. The details of these techniques are given below.

Normalized Deviation

It basically refers to deviation from long term annual mean. The formula used for calculating it is shown below.

$$\text{Normalized deviation} = \frac{(\text{Actual rainfall} - \text{Normal rainfall})}{\text{Normal rainfall}} \times 100$$

The various values depicting different meteorological conditions for different ranges of Normalized deviation are given in table 2. The table depicts that a variation of 20 percent is considered to be normal, while a deficiency of more than 75 percent indicates the occurrence of a drought event.

Table 2: Normalized deviation ranges and its indications

Normalized Deviation	Meteorological Conditions
+20% to -20%	Normal
-20% to -60%	Deficit
-60% to -75%	Scanty
> -75%	Drought

Ordinary Kriging

The basic assumption considered in ordinary kriging is that, that it considers the mean value to be constant. It is not required to know the mean value. This is a major factor for using ordinary kriging in this analysis. The first step while using ordinary kriging is to calculate the experimental semi-variogram. The experimental semi-variogram is a spatial auto-correlation function, analogous to auto correlation function in time series analysis. The experimental semi-variogram was calculated using ILWIS. The values of this empirical semi variogram are shown in table 3 and its plot is shown in figure 2. The lag distance used for this analysis was 50000 metres. The lag distance was selected after many trials so that a stabilised form can be obtained from the experimental semi-variogram.

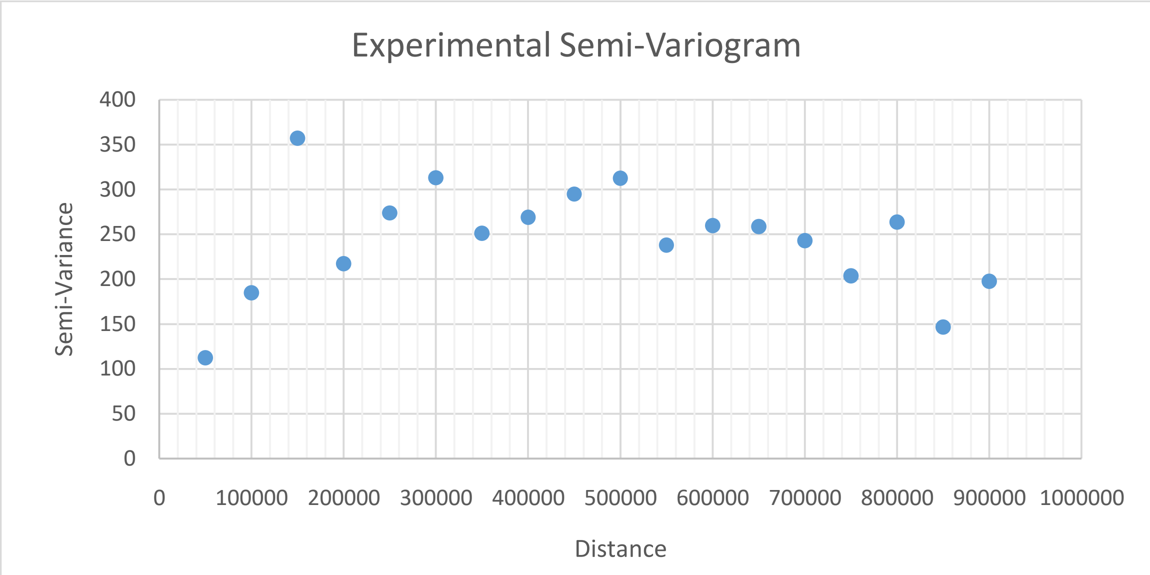

Figure 2: Experimental Semi-variogram plot

Table 3: Experimental Semi-Variance values

Lag Distance (m)	Number of location points	Semi-variance
50000	16	112.33
100000	79	184.78
150000	41	357.11
200000	69	217.34
250000	84	273.74
300000	67	313.05
350000	56	251.04
400000	58	268.95
450000	55	294.82
500000	36	312.43
550000	34	237.83
600000	29	259.72
650000	22	258.66
700000	22	242.9
750000	21	203.73
800000	8	263.58
850000	4	146.63
900000	2	197.67

From figure 2, kriging parameters required for further analysis were computed. The range was found to be 350000 meters, sill was 250 meters and nugget 120 meters. These parameters are advanced parameters inputs in ArcGIS while using spatial analyst tool. After this theoretical semi-variogram model was to be selected out of the various options. The analysis for theoretical semi-variogram is shown in table 4 and figure 3. Three models namely; spherical, exponential and gaussian were examined and the model with the least root mean squared error(RMSE) was selected.

Table 4: RMSE between experimental and model computed values

Semi-variogram model	Lag distance (m)	Nugget	Sill	Range (m)	RMSE (%)
Spherical	50000	120	250	350000	55.19217
Exponential	50000	120	250	350000	73.08241
Gaussian	50000	120	250	350000	8.548825

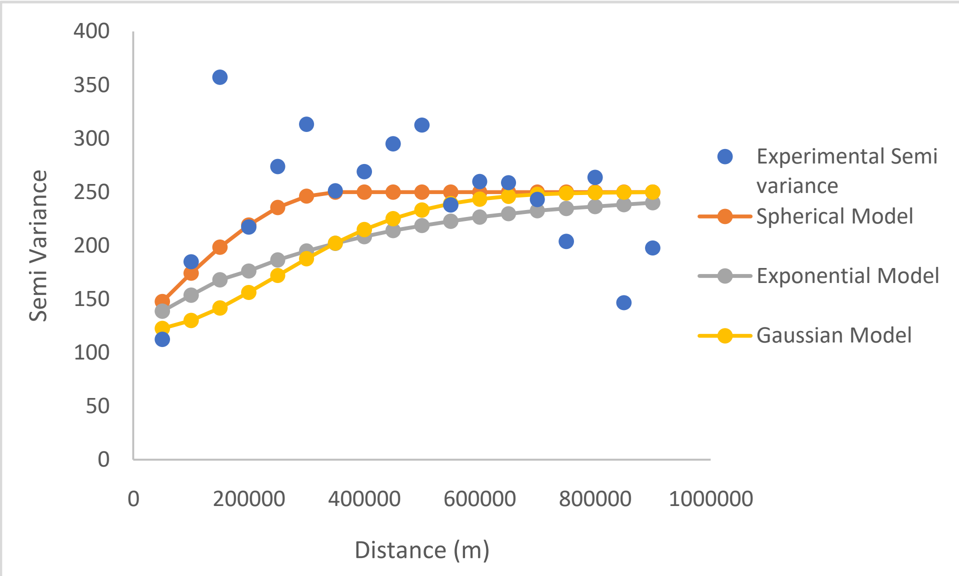

Figure 3: Fitting theoretical Semi-Variogram models

After selecting spherical model as the theoretical model, the final step was to use all the inputs in the kriging interpolation tool of ArcGIS. The final map of Maharashtra, showing the normalized deviation plot is shown in figure 4.

IV. RESULTS AND DISCUSSIONS

From the preliminary analysis shown in table 1, it is clear that both Marathwada and Vidarbha regions receive less rainfall than the state average. On further analysis it can be seen that Marathwada region is the worst drought affected regions. This analysis was supported by the various studies conducted in the past.

On scrutinizing the kriging map, shown in figure 4, it is found that the green zone, which overlaps with Marathwada, is the zone with most negative rainfall deviation (-38% to -54%). A part of this can be attributed to the topography of the state because the rain laden monsoon winds are not obstructed by any natural mountain barriers. The mountain ranges like the Balaghat range are parallel to the direction of south west monsoon winds.

Furthermore, the coastal zone of Maharashtra, receives the highest amount of rainfall (+69% to + 85%). This is due to the presence of western ghats. They are very functional on obstructing the monsoon winds. The eastern most part of Maharashtra, that is the Vidarbha region witnessed values more than Marathwada. The reason for this may be the influence of north east monsoon.

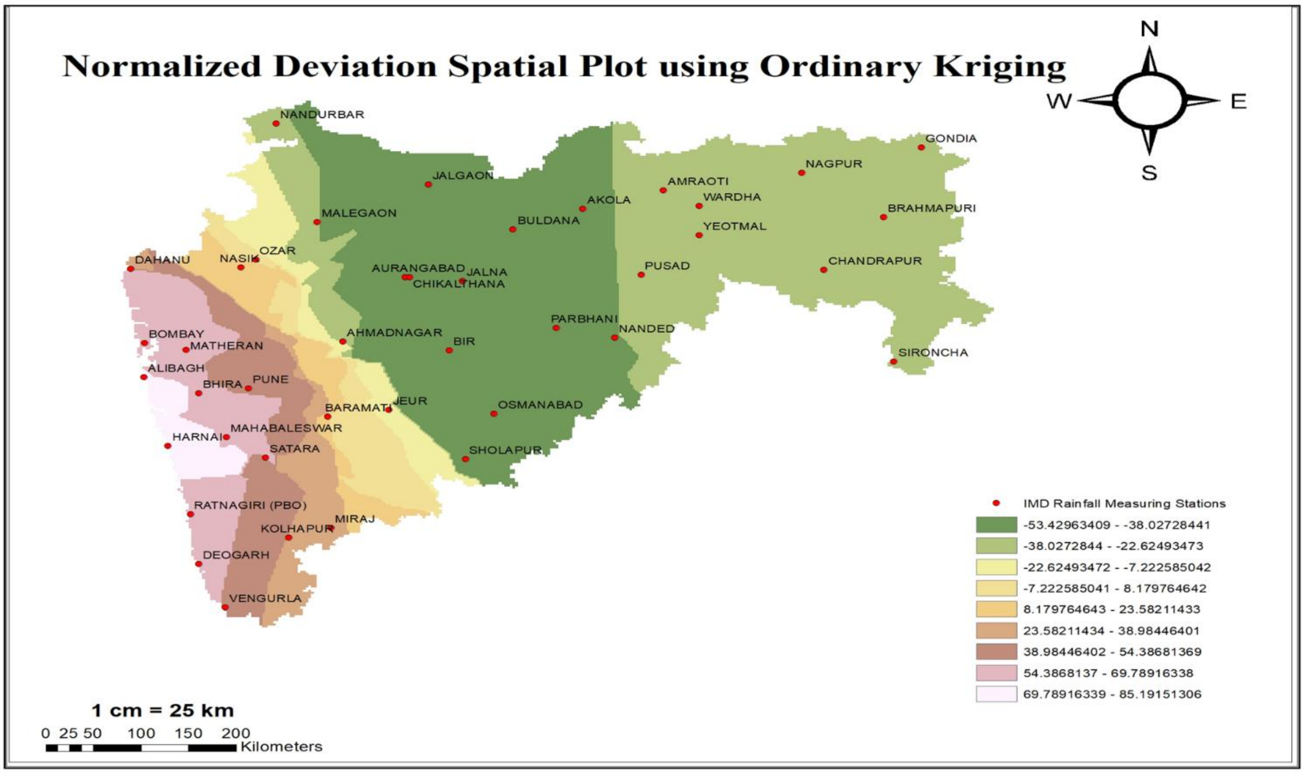

Figure 4: Normalized Deviation plot using Ordinary Kriging

V. CONCLUSIONS

It is clear that there is a large amount variation in rainfall across the state of Maharashtra. Central Maharashtra is the most drought prone area in the state. The precipitation records of this area are required to be monitored regularly in order to reduce the socio-economic impacts of droughts.

VI. ACKNOWLEDGEMENTS

The authors would like to acknowledge the SERB, Department of Science and Technology, Government of India, for providing financial fund to procure meteorological data and Punjab Engineering College (Deemed to be University), Chandigarh, for providing infrastructure to carry out the research. The authors are also grateful to the reviewers whose constructive suggestions may improve the manuscript.

REFERENCES

- Carbone, G. J., Rhee J., Mizzell H. P., and Boyles R. (2008). A regional-scale drought monitoring tool for the Carolinas. *Bulletin of the American Meteorological* Society, 89, 20-28.
- Chen, D., Ou, T., Gong, L., Xu, C. Y., Li, W., Ho, C. H., & Qian, W. (2010). Spatial interpolation of daily precipitation in China: 1951–2005. *Advances in Atmospheric Sciences*, 27(6), 1221-1232
- Davis, J.C. (2011). Statistics and data analysis in Geology. *John Wiley and Sons.*
- Guhathakurta, P. and Saji, E. (2013) 'Detecting changes in rainfall pattern and seasonality index vis-à-vis increasing water scarcity in Maharashtra', *Journal of Earth*
- Kulkarni, A., Gadgil, S. and Patwardhan, S. (2016) 'Monsoon variability, the 2015 Marathwada drought and rainfed agriculture', *Current Science*, 111(7), pp. 1182–1193. doi: 10.18520/cs/v111/i7/1182-1193.*System Science*, 122(3), pp. 639–649. doi: 10.1007/s12040-013-0294-y.

- Kumar, K. and Hariprasad, M. K. A. K. S. (2014) 'Geostatistical analysis of soil moisture distribution in a part of Solani River catchment'. doi: 10.1007/s13201-014-0202-x.

- NIDM (2014) 'Maharashtra geography', Business Recorder. Available at: http://nidm.gov.in/pdf/dp/Maharashtra.pdf.

- Şen, Z. (2015) *Applied Drought Modeling, Prediction, and Mitigation*, *Applied Drought Modeling, Prediction, and Mitigation*. doi: 10.1016/B978-0-12-802176-7.00006-7

- Piazza D. A., Conti F. L., Noto L. V., Viola F., & Loggia, G. L. (2011). Comparative analysis of different techniques for spatial interpolation of rainfall data to create a 140 serially complete monthly time series of precipitation for Sicily, Italy. International Journal of Applied Earth Observation and Geoinformation, 13, 396-408.

- Vicente Serrano, S. M., Sánchez, S., &Cuadrat, J. M. (2003). Comparative analysis of interpolation methods in the middle Ebro Valley (Spain): Application to annual precipitation and temperature. *Climate Research*, 24, 161 –180