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Estimation of Seasonal and Annual Precipitation Using Interpolation Multivariate Methods to identify areas prone to wind erosion (case study: Khorasan Razavi province)

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ABSTRACT

There are two basic conditions necessary for the occurrence of wind erosion in widespread locations. Firstly it must occur regions that have constant winds and the second condition is that the soil must be dry so that it can be easily transported by wind and its average annual precipitation must be less than 250 mm. This study aimed to estimate seasonal and annual rainfall of Khorasan Razavi province with a 20-year period using three geostatistical methods: kriging, IDW and Cokriging. Results showed that between the three geostatical methods that were used in this study, Cokriging showed higher accuracy than the other two methods (based on RMSE and ME less), so the final maps were prepared using his method. Based on the analysis of statistical data in the SPSS software and the variogram , the most appropriate data model for the seasonal and annual precipitation maps that was selected was the ArcGIS9.3 software. According to the maps, the more north you go the more precipitation occurs; which shows the correlation between height and precipitation. Thus the correlation coefficient between height and seasonal and annual precipitation is stronger, and there will be higher accuracy of prediction through Cokriging. These factors are also effective in wind erosion when the amount of annual rainfall and distribution is in different seasons. According to the results obtained, areas other than the north and northwest, particularly in the eastern provinces are prone to wind erosion.

Introduction

Wind erosion often occurs in arid and semi-arid regions because of the limited amount of rainfall in these areas, which makes the soil surface remain dry for long periods. It is also a limiting factor for vegetation growth and both of these factors make the soil susceptible to wind erosion. In general, areas that are exposed to wind erosion with an annual rainfall less than 250 mm, or areas where the rainfall distribution varies in different seasons makes the soil more prone to erosion (Refahi, 1388). On the other hand spatial rainfall is influenced by climatic conditions and morphological parameters of the earth. An important factor in estimating rainfall is to access to previous data and the distribution of the regions. Precipitation forecast is difficult in places with lots of reliefs. So that in flat areas, predicted rainfall has fewer problems (zare Chahouki, 1390).

For estimating rainfall in watershed level, a method is needed which could determine the moderate climate phenomena with acceptable and maximum precision. In order to calculate the average statistics of climate, particularly rainfall, the Thiessen method (Thiessen, 1911) was invented about a century ago. Of course, application of this method was more limited after the geostatistical approach was expanded in 1960 (sarangi, 2005). The first experience for the application of geostatistical methods was done in 1919.

Then in few decades later, Matheron and Krige by publishing articles founded the base of modern statistics earth (Matheron, 1962; Krige, 1951). Geostatistical methods especially Kriging method checks the spatial correlation between the observational data through the modified function; this method is capable of modeling non-deterministic time and spatial phenomena (Nejad, 2005). Thus, according to the results of extensive research within and outside the country, Geostatistical methods for estimating precipitation gradually as the method was introduced in areas without watershed statistics . The primary use of land statistics in the estimation of rainfall in 1973 was presented *by Delfiner & Delhomme* (pardo,1998). Since then different applications of geostatiscal has been expanded. Cokriging is one of the multivariate geostatistical methods which estimate the correlation of spatial between 2 variables or more Provided that the variables are correlated with the location. This method has much accuracy for showing affection on rainfall. And also, this method is used in some occasions by decreasing estimated variance, which the sampling of the variables associated with high costs or difficulties. Researchers such as Bogaert (1995), Martınez (1996), Pardo (1996),) Deirasme 2000), Goovaerts (2000) used auxiliary variables for hydro Climatic varies (particularly annual precipitation).

Goovaerts(2000) reviews three methods such as simple kriging multivariate geostatistical method with a simple average, Kriging with trend output and Cokriging, for mapping precipitation and annual temperature from data of 36 climatic

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stations in a region at a level of 500 KM^2 in the Portugal. The result showed that among the compared methods, multivariate methods Cokriging had higher accuracy.

Moral (2009) compared methods such as normal, simle, general Kriging with 3 methods of multivariate geostatistical method (height was used as a covariate) for data of the rainfall of 136 pluviometer stations in south west of Spain.

Zhang and Srinivasan (2009) compared eight different methods such as theasen, weighted inverse square, simple kriging, ordinary kriging and four versions of multivariate methods Cokriging rotation (SD) external to predict the precipitation of rain 31 pluviometer stations in Lohe watershed which is stated in yellow China River Basin.

Mutual evaluation results showed that the two versions of kriging with external rotation, the covariates elevation and location coordinates of the stations were used, the correlation coefficient between predicted and actual data is higher. The average method error was less than other methods. Due to the possible use of geostatistical methods, rainfall and temperature maps based on data from weather stations annually made with high accuracy.

Zare Chahouki and colleagues (1390) estimate seasonal and annual rainfall using multivariate interpolation methods in the Alborz range in the province concluded that Cokriging method with regard to operating altitude estimated as auxiliary agent, offers detailed information on rainfall amounts.

This study analyzes the seasonal and annual rainfall using geostatistical methods to find the best features, and seasonal and annual rainfall distribution model using the altitude auxiliary parameter. Accordingly, Susceptible to wind erosion on areas identified in the study area and provide comprehensive management of Weber based solutions that prevent the spread of the destructive effects of this work is a way to deal with desertification.

Materials and Methods

Study site

In this research study area, Khorasan Razavi province located in North East of Iran, with an area of approximately 128420 square kilometers, equivalent to 8/7% of total area allocated to the country. Taking the position that Iran's map is shown in Figure 1. Natural position of Khorasan Razavi is divided into two parts: North and South part. The northern part is mountainous which in its areas fertile plains has been created and proper conditions for developing agriculture and animal husbandry have been provided. The northern part is consisted of desert Plains with low hills which faced with lack of vegetation cover and generally its climate is changing. Extent of province and factors such as, high mountains, desert regions, away from the sea and different winds caused to have different climates in different regions. Air temperature increases in the north to the south, but the annual rainfall is reduced. High region of province (heights of Hezarmasjed- Binalood) has cold mountainous climate.

Methods

In this review after matching calendar's station of rainfall survey Ministry of Energy and meteorological organization based on the solar calendar, reconstruction of incomplete statistics and elicitation of seasonal and annual precipitation of 22 pluviometer stations checked the normalization of data by the Test Kolmogorov-Smirnov in the SPSS software.

And also, stations with suspicious statistics were deleted and finally 15 stations were used for analyzing and just one of them was located out of border. Geographic location of the stations in Figure 1 and features geographic and seasonal and annual rainfall statistics are listed in Table 1.

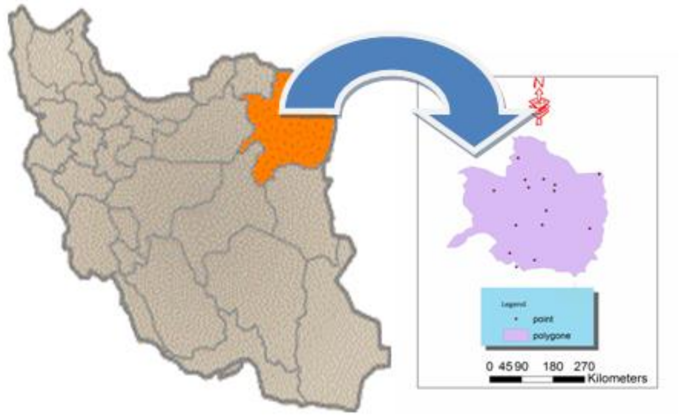

Figure 1. The study area location and distribution of rainfall stations surveyed in the study area

Seasonal and annual precipitation of 15 pluviometer stations were considered as the primary variables and the height above sea level as a covariate was considered too. Maximum and minimum height belongs to the Neishaboor station with 1795 m and the Sarakhs station with 235 m above sea level respectively. For data analysis and mapping based on the data of pluviometer stations, the variogram was prepared and also according to the symbols and high correlation between rainfall and elevation for seasonal and annual precipitation, from geostatistical method Cokriging in the ArcGis 9.3 software were used.

Cokriging use in cases where a variable is not enough sampling and based on these estimates cannot be done with the desired accuracy. In such cases, considering the spatial relationship between this variable and other variable that it is a good sampling, can correct the estimate. However, due to difficulties in cross-variogram model variables there, Cokriging like Kriging is performed in two forms: point and block. In fact, as in classical statistics there are multivariate methods, in geostatistics can also by cokriging method and according to correlation between different variables, value of a unknown variables can be estimated.

Cokriging equation method is as follows:

$$Z^*(xi) = \sum_{i=1}^{n} \lambda i.Z(xi) \sum_{k=1}^{m} \lambda_k.y(x_k)$$

Z (xi): estimated value for point xi

λ_i : Weight to the variable z

λ_k : Weight to the variable Y

Z*(xi): observed value of main variable

y(xk): observed value of Auxiliary variable

Conclusions

Tables 2 and 3 are shown the results of seasonal and annual rainfall data and their coefficient correlation with elevation above the sea. As can be observed between the annual and seasonal precipitation and elevation, there is a high correlation and changes with elevation and rainfall for all seasons is at the 95% significant level. This directly shows that precipitation increases with elevation. So, because of high correlation between rainfall and elevation, Cokriging method than other methods, is in priority.

Researchers such as Mohammadi and Misaghy (1384), Diodato (2005) Zhang & Srinivasan (2009), Moral (2009), Goovaerts) 2000), Zare et al (1390) also used this method in their work. After statistical analysis of data, the empirical variogram for elevation of studied pluviometry stations was prepared by using the software ArcGIS9.3 (Figure 2). According to the variogram and its evaluation results, the spherical model is appropriate for the variogram. The results show that the overall model fit in the space between zero to 593 km are important and results in greater distance of 593 km is not very sensitive to changes (Figure 3).

The variograms of annual and seasonal precipitation and variogram of elevation are shown in figures 3 to 7. Components of variogram which are shown in the figures include Work piece of the range (spatial or time distance after that between sample, after that, the variable region in the adjacent areas do not have much impact on each other) threshold (is a value ratio of constatnt with random variation which is equal to the studied variable of the total variance (Johnson, 2001)) . Annual variogram (figure7) according to the correlation coefficient 0.66 and threshold of 1461 is expected to provide the most accurate estimation of rainfall in this season. Autumn variogram (figure5) which its correlation coefficient is less than annual and also, its impact will be less than the annual range.

Variogram parameters and statistics of the cross with two standard methods of evaluation ME and RMSE for all seasons and annual rainfall are mentioned in Table 3. To estimate seasonal and annual precipitation Cokriging interpolation method was used. Length of height impact for estimating accuracy is depends on the degree of correlation between precipitation and elevation.

By applying Cokriging interpolation method, annual precipitation and precipitation distribution maps were prepared for all seasons (figures 8 to 12), which concluded that by increasing elevation , annual precipitation is increased that parts of North and North West in terms of rainfall maps is in good condition. And due to lack of good condition are susceptible to wind erosion. Adversely, East and North East regions are most at risk of wind erosion. Estimation variance maps Cokriging showed a similar process but decreased.

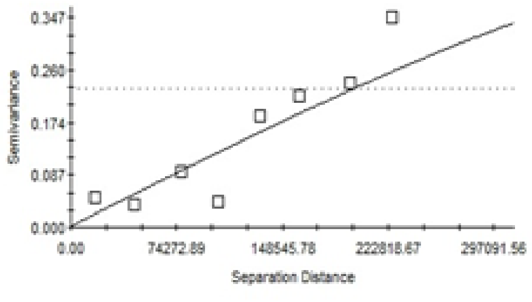

Figure 2. variogram for height of studied area

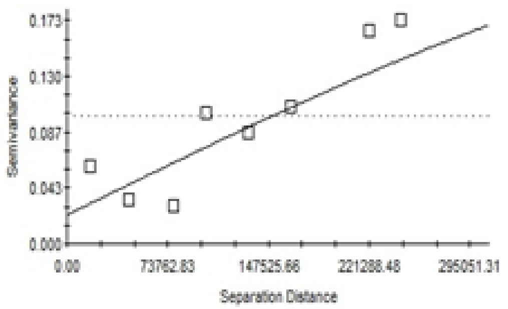

Figure 3. Variogram for precipitation of spring

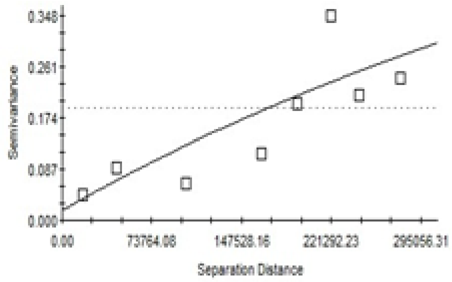

Figure 4. Variogram for precipitation of summer

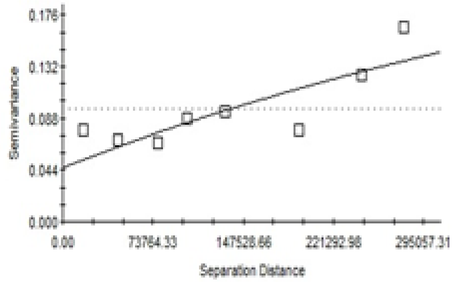

Figure 5. variogram for precipitation of autumn

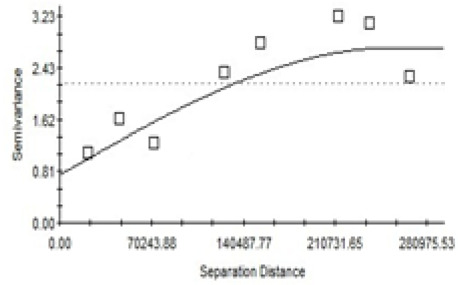

Figure 6. Variogram for precipitation of winter

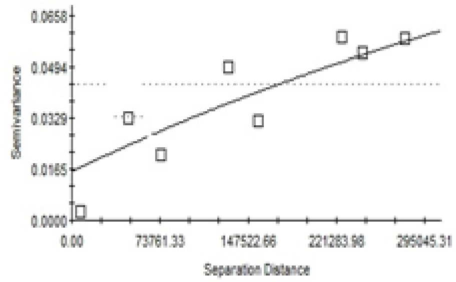

Figure 7. Variogram for annual precipitation

Discussion and conclusion

In this study geo statistical methods included IDW, Kriging and Cokriging for estimating annual and seasonal precipitation are used in order to choose the best method with lowest per cent accuracy. It is concluded that among those geo statistical models, Cokriging has been selected as a best method. In this method height above the sea level was considered as a auxiliary variable and annual and seasonal precipitation were selected as a main variable. In most previous studies, geo statistical methods were used to analyse and evaluate monthly precipitation and, Different interpolation methods, including statistical and geostatistical methods for regions with low roughness Goovaerts (2000) and in mountainous areas Sarangi (2005) were compared multivariate geostatistical methods (Cokriging) had a minimum prediction error. In this review, instead of monthly precipitation, Multivariate geostatistical methods to predict performance in seasonal and annual precipitation were investigated along with their forecast error variance.

Table 1: Geographical and statistical properties of pluviometer stations of study area

Annual rainfall (mm)			Property of stations			
minimum	Maximum	average	Height above sea level(m)	Latitude (degrees east)	Longitude (degrees North)	Name of stations
158/1	350/6	241/8	1213	36 16	58 48	Neishaboor
143/6	390/2	246/7	992	36 15	59 38	Mashhad
49/8	366/5	145/1	956	34 21	58 41	Gonabad
129/3	319/1	307.9	1176	36 29	59 17	Galmakan
145/7	299/1	213/4	1109	35 12	58 28	Kashmar
99/3	259/8	178/6	235	36 32	61 10	Sarakhs
115/8	416/5	294/2	1450	35 16	59 13	Torbat heidariyeh
90/2	238/2	168/2	950	35 15	60 35	Torbat jam
127/2	285/2	191/3	977	36 12	57 43	Sabzevar
117/6	358/1	216/5	1770	35 39	59 21	Asadabad
111/1	357/3	228/8	1030	36 20	59 39	Daneshkade
116/3	321/1	254/4	1440	34 07	58 23	Fath abad
195	479/4	356/6	1795	36 29	58 42	Bar
77/7	241/4	186/9	1370	34 31	58 11	Bajestan
203	436	307/6	1287	37 40	58 30	Ghoochan

Table 2: Correlation between annual and seasonal precipitation with altitude in the study area

	Spring	Summer	Autumn	Fall	Annual	Elevation
Spring	1					
Summer	0/76**	1				
Autumn	0/79**	0/62*	1			
Fall	0/55**	0/60*	0/86**	1		
Annual	0/87**	0/73**	0/95**	0/93**	1	
elevation	0/60*	0/59*	0/62*	0/56*	0/66*	1

Table 3: Annual and seasonal rainfall characteristics in the study area

number	S.D	Average(mm)	Rainfall
15	46/65	229/61	Annual
15	18/50	59/73	Spring
15	1/48	3/86	Summer
15	15/70	48/14	autumn
15	26/65	117/86	fall

Table 4. Variogram model features seasonal and annual precipitation in the study area

ME	RMSE	C_0	C_0+C	C/C_0+C	A_0	The best model	Rainfall
1/006	14/920	0/022	0/234	0/905	610000	Spherical	spring
0/099	1/229	0/017	0/729	0/977	604000	exponential	Summer
-0/744	13/530	0/046	0/293	0/842	611000	exponential	Autumn
-1/326	26/050	0/750	2/740	0/726	254200	Spherical	Winter
-1/043	51/450	0/015	0/129	0/880	612200	Spherical	annual

According to our result, Cokriging method for predicting the location of precipitation and also for finding characteristics and preparation of seasonal and annual rainfall distribution model has a simple approach that provides acceptable results like Moral (2009) and Zhang & Srinivasan (2009). The relationship between rainfall and altitude is significant for all seasons.

Due to this, range of high impact, accuracy of estimators and rainfall favoured estimated by Cokriging multivariate is depends on correlation between height and estimated precipitation. In this study between annual precipitation and height above sea level is a high correlation, and results of Cokriging interpolation have high accuracy which is matched with results of Zare et al (1390). So, the correlation coefficient of rainfall and pluviometry stations is more, the precipitation forecast is more accurate and And with previous research results Goovaerts (2000) and Moral (2009) also is consistent .and on the other hand, the range of the annual precipitation is also greater than other seasons. Reached the conclusion that if the correlation coefficient of rainfall and the height is greater, the range of variogram will further. The results show that the best variogram model for the annual and spring and winter is spherical model. However, the best model for the summer and fall seasons is the spherical model. On the other hand, wind erosion in arid and semi-arid often occurs because a little rain in these areas causes the soil surface remain dry and provided the conditions for wind erosion. According to the results, except the north and North West province with more than 250 mm rainfall, the rest of the region especially the east and north east is more prone to wind erosion.

And also prepared the maps for different seasons can be observed that the rainfall distribution is different in different seasons and provides the conditions for wind erosion which cause land degradation and desertification which from economic and social aspect will lead to disastrous. Then we can prevent the wind erosion by the management and implementation of programs.

The results of this study, because the auxiliary variable method uses Cokriging enhances accuracy. On the other hand, due to the complexity of rainfall, adding auxiliary variables such as temperature, distance from the sea, wind speed and direction and air pressure and altitude in addition to comparing different models Cokriging, accurate estimates can be increased with this method programs to be able to control wind erosion and to prevent losses and the resulting losses.

References

1)Bogaert, P., P. Mahau & F. Beckers, 1995. The Spatial Interpolation of Agro-Climatic Data. FAO: Rome.

2)Clark, I. & Harper, W., 2000. Practical Geostatistics 2000. Ecosse North America Lic, Columbus, Ohio,USA.

3)climatological rainfall mean using data on precipitation and topography. International Journal of Climatology18: 1031-1047.

4)Cressie, N. & C.K. Wikle, 1998. The variance-based cross-variogram: you can add apples and oranges.Mathematical Geology 30(7): 789-799.

5)Deirasme, J., J. Humbert, G. Drogue & N. Freslon, 2000. Geostatistical interpolation of rainfall in

6)Diodato N., 2005. The influence of topographic co-variables on the spatial variability of precipitation over small region of complex terrain. Int. J. Climatol. 25: 351-363.

7)Diodato, N. & M. Ceccarelli, 2005. Interpolation processes using multivariate geostatistics for mapping of climatological precipitation mean in the Sannio Mountains (southern Italy). Earth Surface Processes and Landforms: 30, 259-268

8)Ella, V. B., S.W. Melvin, & R.S. Kanwar, 2001. Spatial analysis of NO3-N concentration in glacial till. Trans. ASAE 44(2): 317-327.

9)Goovaerts P., 2000. Geostatistical approaches for incorporating elevation into the spatial interpolation of rainfall. Journal of Hydrology, 228(1-2): 113-129.

10) hassani pak ali. 1386.Geostatistic. Publications university of Tehran. Second Edition.

11) Isaaks E.H. & R.M. Srivastava, 1989. An Introduction to Applied Geostatistics. Oxford University Press: New York, 592 p.

12) Johnston K, J.M. Ver Hoef, K. Krivoruchko & N. Lucas, 2001. Using ArcGis Geostatistical Analyst.ESRI, 48 p.

13) Karamoz M. & S. Araghi Nejad, 2005. Advanced Hydrology, Amirkabir University Press, 464 p.

14) Kitanidis P.K., 1997. Introduction to Geostatistics: Application to Hydrology. Cambridge, U.K.: Cambridge University Press, 272 p.

15) Marqu´ınez J., J. Lastra & P. Garc´ıa, 2003. Estimation models for precipitation in mountatinous regions: the use of GIS and multivariate analysis. Journal of Hydrology 270: 1-11.

16) Mart´ınez-Cob A., 1996. Multivariate geostatistical analysis of evapotranspiration and precipitation in mountainous terrain. Journal of Hydrology, 174: 19-35.

17) Misaghi F. & M. Mohammadi, 2006. Zonation of rainfall data using classical statistical methods and land statistics and comparison with artificial neural networks, Journal of Agricultural Sciences, 9(4).

18) Moral F. J., 2009. Comparison of different geostatistical approaches to map climate variables: application to precipitation. Int. J. Climatol, 2009. DOI: 10.1002/joc.1913

19) Mountainous areas. In Proceedings of Meeting geoENV III - Geostatistics for Environmental Application, Avignone. Kluwer Accademic Publishers: 57-66.

20) Pardo-Ig´uzquiza E., 1998. Comparison of geostatistical methods for estimating the areal average

21) Refahi hosseingholi.wind erosion and Wind erosion and its control. Publications university of Tehran.five Edition.p5-20

22) Sarangi A., C. A. Cox, C.A., 2005. Madramootoo. Geostatistical methods for prediction of spatial variability of rainfall in a mountain region. Transactions of the ASAE, Vol. 48(3): 943-954.

23) zare chahouki Asghar, mohammad ali zare chahouki. 1390. Estimation of Seasonal and Annual Precipitation Using Geostatistical Methods (Case Study: Southern Alborz of Semnan Province).Journal of Range and Watershed Management, Iranian Journal of Natural Resources, Vol. 64, No. 1, 2011. Pp.39-51.

24) zehtabian Gh, Mohammad Asgary,1386. Research projects Spatial analysis of groundwater quality characteristics Groundwater Area Garmsar.

25) Zhang X. & R. Srinivasan., 2009. GIS-based spatial precipitation estimation: a comparison of geostatistical approaches.