VALIDATION OF SPATIAL INTERPOLATION TECHNIQUES IN GIS

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KEYWORD: GIS- Geographic Information System, IDW – Inverse Distance Weighted, Interpolation

ABSTRACT

Spatial Interpolation is one of the very powerful analytical tools in the field of spatial sciences. It is useful to convert point data into surface or grid data. The spatial analyst extension in ArcGIS employs several interpolation tools and methods. Interpolation is a procedure used to predict the unknown place values using known location values. On the other hand surface interpolation converts desecrate data into the continuous data using some mathematical equations. Interpolation techniques estimate data between known points as well as outside the known points which call extrapolation.

Many diversities of interpolation techniques are available to predict values for unknown points. Inverse Distance Weighted Method (IDW), Spline Method and Kringing are most common methods available in GIS. Rainfall estimation is an integral component of different research areas and specially hydrology and agro-climatology. This study focuses on assessing the suitability of various interpolation methods in term of their accuracy, for generating rainfall surface based on the main meteorological observatories in Sri Lanka.

In this study, result of five different interpolation techniques (IDW – Inverse Distance Weighted, Kriging, Natural Neighbour, Spline and Trend) were compared using ArcGIS 10.1 and annual monthly rainfall data for ten years from 2003 to 2013 for twenty two metrological observatories in Sri Lanka were analysed. Main meteorological observatories data used to create surface data and minor meteorological observatories data were used for accuracy assessment. Cross-validation method were used in this study and using surface data, predicted values extracted to minor meteorological locations and those values compared with known actual rainfall values available for minor observatories. Finally F test was stablished to assess the accuracy of interpolated data.

This study reveals that the most suitable interpolation method for creating rainfall surface for Sri Lanka is Spline method. Further this study discloses that the Spline method more suitable to analyze both annual rainfall data as well as monthly rainfall data. Other four methods were demonstrated very high difference between actual rainfall values in minor observatories and the predicted values. However, the Trend interpolation method shown very poor result in predicting rainfall surface data for annual as well as monthly rainfall data.

INTRODUCTION

Some of special data are recorded as point data means those data collecting based on special locations. Examples are all climate and weather data, soil tested values, water quality parameters and etc. so estimating values at other locations requires some accurate technique. In GIS have produced several techniques for interpolation. Spatial Interpolation is one of the very powerful analytical tools in the field of spatial sciences and it is a procedure used to predict the Unknown place values using known location values. On the other hand surface interpolation converts desecrate data into the continuous data using some mathematical equations.

"Accurate precipitation data are of prime importance for many environmental studies, especially if related to water resources. At small scales, the use of measurements from individual rain gauges might be appropriate. However at larger scales, it is required to draw special attention to the appropriate representation of the spatial precipitation patterns, which are usually interpolated from point measurements" (Wagner Paul D. *et al*., 2012). However, spatial variability of rainfall adds to the complexity of estimating rainfall and is a key factor that must be incorporated into estimations. There are a number of approaches that hydrologists use to account for spatial variation in rainfall estimates (Knight Y., 2005). Therefore spatial interpolation is more useful in rainfall data if there are sufficient rainfall locations around the study area.

In Sri Lanka more than 300 major and minor stations can be identified. So the interpolation methods can be applied well in this field. However, accuracy of the estimated data is very important. There are many interpolation methods can be used in this field and most commonly IDW (Inverse Distance Method) and Kringing are used. However, those methods have included different techniques and their degree of complexity and predictive accuracy are different. Also it's depend on the data type which we used for analyze. So identifying the most suitable interpolation method is very important.

Spatial interpolation techniques are widely used to estimate seamless spatial coverage of rainfall over large areas, yet there is little consensus on the optimal interpolator for rainfall, especially where spatial rainfall pattern is highly variable (Plouffe C.C.F. *et al*, 2015). However, different methods used to create rainfall surface and there are different conclusions regarding the rainfall data represent in Sri Lanka. So better understanding of proper application is important.

Precipitation data are very important for many field of the environment and it is a very sensitive case for many studies. Such as, water resource management, Environmental management, Hydrology, Agro-Climatology and agriculture are most important. This study focuses on assessing the suitability of various interpolation methods in term of their accuracy, for generating rainfall surface.

OBJECTIVES

Sri Lanka is small country but rainfall variation is very high. So most accurate method of interpolation is very important. In this study, the mainly amid to Comparing five interpolation methods and understanding their suitability for rainfall data in Sri Lanka. Otherwise, the study identify the most accurate interpolation methods for monthly rainfall data and also to identify the most accurate interpolation method for annual rainfall data.

According to the above objectives, finally, the study tried to explain most appropriate interpolation method and their accuracy for rainfall data analysis in Sri Lanka.

MATERIALS AND METHODS

Study Area

The study was conducted in Sri Lanka and it is situated in the Indian Ocean, off the southeastern tip of the Indian subcontinent. When considering the absolute location, it is situated between North Latitude 5^{o} – 10^{o} and East Longitude 79^{o} – 80^{o}. Total area of study area is 65,610 sq km. The climate is tropical, and weather is characterized by two seasonal monsoons. The northeast monsoon typically lasts from December to February, while the southwest monsoon lasts from April until September. The southwest area of Sri Lanka receives significant rainfall particularly during the southwest monsoon season, while the northern and eastern regions of the country become predominantly dry during this time. There are also two inter-monsoonal seasons, which last from March to April, and October to November. During these inter-monsoonal seasons, Sri Lanka can experience considerable amounts of convectional rainfall" (Plouffe C.C.F *et al*., 2015). The study area map has shown in figure 1.

Materials

In this study, mainly collected rainfall data for weather stations in Sri Lanka. Those data were collected in different categories. Especially twenty two main Meteorological Observatories in Sri Lanka were identified for the data analysis. The twenty two main Meteorological Observatories are Colombo, Jaffna, Trincomalee, Hambantota, Rathnapura, Anuradhapura, Katugastota, Bandarawela, Nuwara Eliya, Kurunegala, Puttalam, Galle, Badulla, Mannar, Vavuniya, Mahailukpallama, Batticaloa, Katunayake, Rathmalana, Potuvil, Monaragala and Polonnaruwa. Minor Meteorological Observatories were used to Accuracy assessment and there are more than 300 Minor Meteorological Observatories in Sri Lanka. However, in this study were used only 20 Minor Meteorological Observatories for the accuracy assessment of the interpolation methods. For using all stations are increasing time and cost and data collecting is very difficult. So 20 Minor Meteorological Observatories were selected randomly for all over the study area. Locations of Major and Minor Meteorological Observatories are shown in Figure 2.

Precipitation data were collected using this Meteorological Observatories and it was collected for different time period. Mainly rainfall data collected for ten year period in 2003 to 2013. Data were analyzed within two year period such as 2003, 2005, 2007, 2009, 2011 and 2013. In this period, all annual rainfall data as well as monthly rainfall data were collected. Rainfall data were collected form Department of Meteorology, Sri Lanka.

Figure 01: Map of Study Area

Methods

In this study Method can be divided into three parts. Such as;, Cross Validation, Create Rainfall Surfaces and Estimation Accuracy.

Cross Validation

The study mainly used Cross Validation Method for identify the most suitable interpolation method for rainfall data in Sri Lanka. In this method, the study used only twenty two Major Meteorological station's data for interpolation and other Minor Meteorological Observatories were deleted. Main station's data helped to predict rainfall for all over the study area and deleted locations were used to extract estimated rainfall data. All estimated rainfall data were compared using their actual rainfall values to identify the accuracy of interpolation methods.

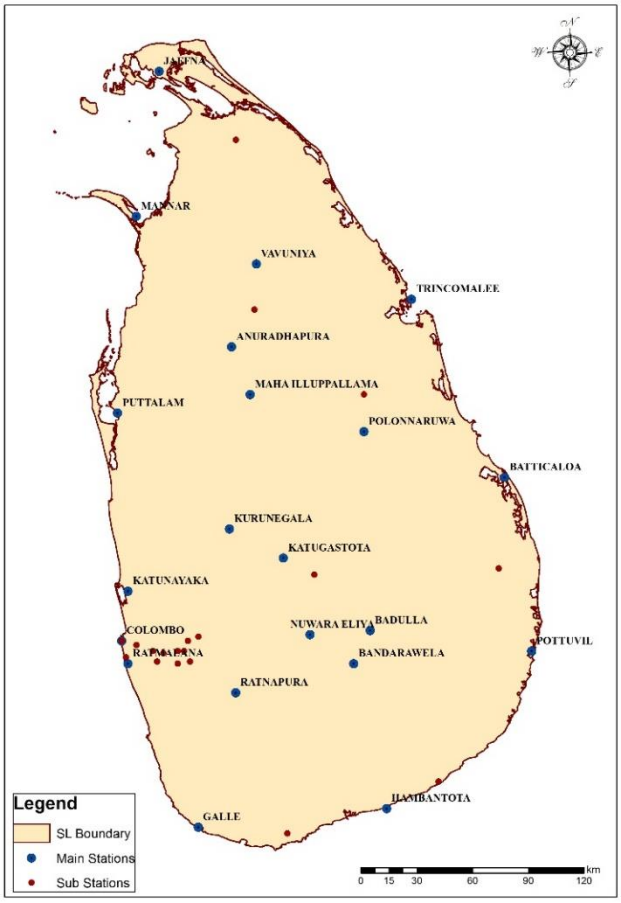

Figure 02: Major and Minor Meteorological Observatories, (Department of Meteorology, 2016).

Create Rainfall Surfaces

In this study have tried to create rainfall surface Using interpolation method. Surface is represented raster (Grid) format and there are X, Y coordinates. The special thing of this method is Z values. The surface tools are required Z values and for X, Y location has only one Z value. Surfaces are continues and Z values estimate for unknown locations. However, if surfaces have X, Y, Z values those are not true three dimensional surfaces. It was very useful to depict the rainfall pattern. In this method statistical tools as well as mathematical tools can be identified and surfaces created in its simplest form storing X Y and Z values. Change characteristics values represented by Z values.

Surface structure can be mentioned as cells of equal size that are arranged in rows and columns. Each cell contains cell values that represent a change in Z values. To create a surface grid in ArcGIS, It has several interpolation tools. All of methods are help to predict the values of unknown point locations. It can be identified a relationship of Z values and create a spatial pattern for that data. This procedure can be identified using Figure 3.

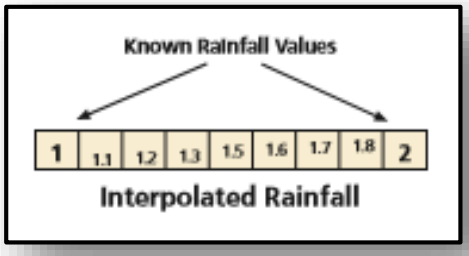

Figure 03: Interpolation (Childs C., 2004)

There are two type of interpolation techniques. Such as deterministic and geostatistical. Deterministic interpolation techniques create surface based on measured point or mathematical formulas. For example; IDW (Inverse Distance Method) and Trend. Geostatistical interpolation method are based on statistical method and advanced predicted models are used. For example Kriging (Childs C., 2004).

In this study, five different interpolation techniques were compared using ArcGIS 10.1. Interpolation methods are IDW – Inverse Distance Weighted, Kriging, Natural Neighbour, Spline and Trend. Those Methods can be identified Under the Spatial Analyst tool in ArcGIS. There are different method can be identified for different interpolation method.

IDW – Inverse Distance Weighted

IDW method should be used when the sample points will be good enough for the study area. IDW predict cell values using linear weighted combination set of sample points and the weight assigned using distance of input points (Naoum S *et al*., 2004).

Spline

In Spline method estimates values using mathematical function that minimizes overall surface curvature. It is created a smooth surface and it is the best method for representing the smoothly varying surface of the earth surface (Childs C., 2004).

Kriging

The Kriging method totally based on statistics. It tries to assume that the distance or direction between sample points using spatial correlation. It can be used to explain variation in the surface (Childs C., 2004).

Natural Neighbor

This method can be used for both interpolation and extrapolation in ArcGIS. It is generally works well with clustered scatter points. This method also used weighted average method (Childs C., 2004).

Trend

Trend method is also a statistic method and it is using a least – squares regression fit. The resulting surface rarely passes though the input points. This method is identified trends of sample data and predict other location values (Naoum S *et al*., 2004).

Those five method were used in this study and annual and monthly rainfall data were analyzed using five methods.

ESTIMATION ACCURACY

The study conduct an Accuracy Assessment for five interpolation methods to identified most appropriate method for rainfall data analysis. All estimated values extract from rainfall surfaces using ArcGIS tool called "Extract Values from Points". Those values compared with actual observed rainfall values of these sub stations for the same period. The most accurate values will be identified as the most suitable method for rainfall analysis in Sri Lanka.

In this method statistic F test were used to reveal variation of both data. F test were done using SPSS and F values. This is very important for the identification for equality of two variances. The Hypothesis tests were done to define the accuracy of estimated data using standard F table values. The methodology can be shown in figure 4.

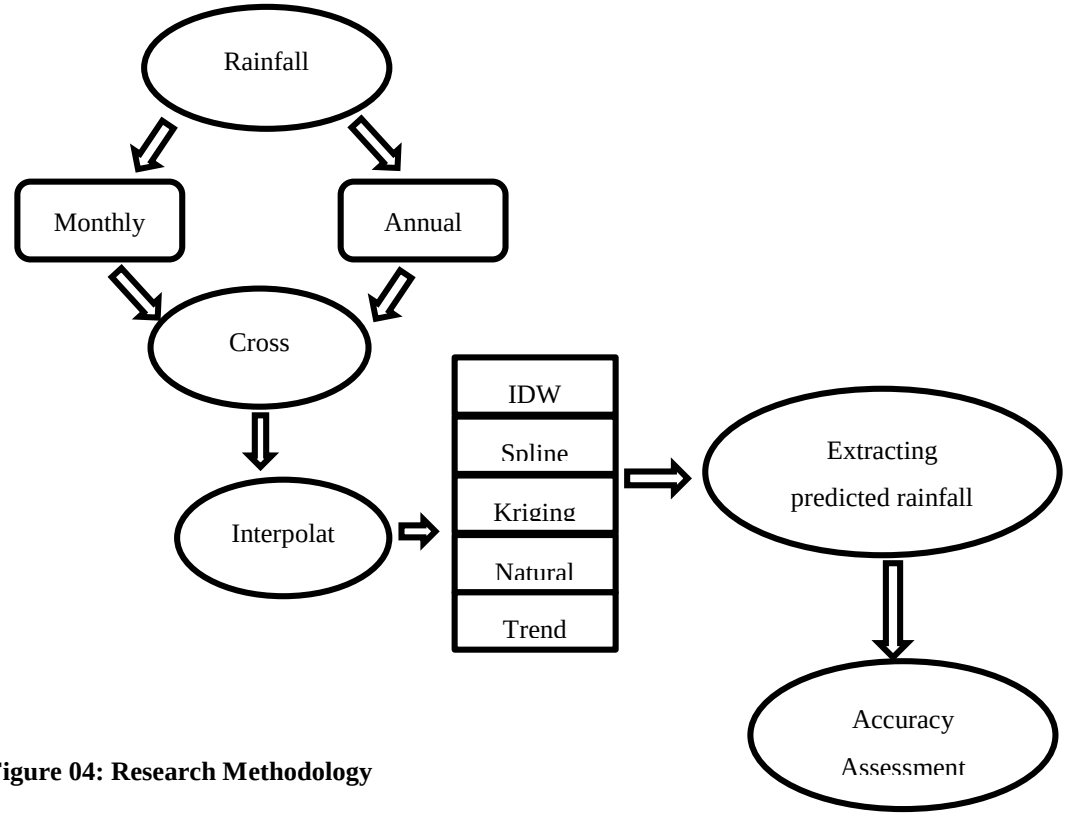

Figure 04: Research Methodology

RESULTS AND DISCUSSION

In this study both annual and monthly rainfall data were analyzed. A total of 30 rainfall surfaces are created for annual rainfall data and 20 surfaces are created for the monthly rainfall data. Monthly data were taken for May and December. It was indicated two different rainfall pattern in Sri Lanka; South East Monsoon and North East Monsoon.

According to the all result different surfaces can be identified. Kriging, IDW and Spline were shown some similarity and other two methods (Nearest Neighbor, Trend) were shown different surfaces. According to the 2003 and 2013 rainfall surfaces (figure 5 and Figure 6) can be identified their differences. Those interpolation methods demonstrated to identify variation of local rainfall but using different methods. According to the both figure 5 and 6, some surfaces are shown similar distribution and some are shown different distribution pattern. IDW, Kriging (Ordinary), Natural Neighbor and also Spline interpolation methods are estimated rainfall in more similar pattern. Their high values and low values aggregated to the same area. However, Kriging (Universal) and Trend interpolation methods are shown different rainfall distribution pattern over the study area. Therefore, these two methods shown highest differences between observed rainfall and estimated rainfall values. According to the F test those two methods were rejected and those are not suitable for the rainfall analysis in Sri Lanka. This also shown in scatter plot (figure 7) and R value shown as low value and negative relationship.

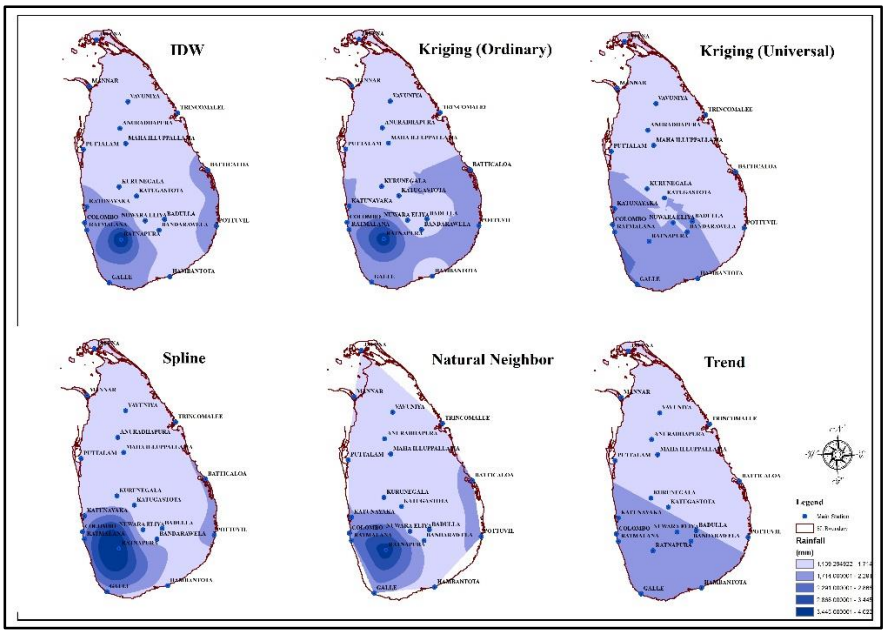

Figure 5: Different Rainfall Surfaces in 2003

Consideration of other four methods (IDW, Kriging (Ordinary), Spline, Natuaral Neighbor) shown some similarities. However, those have been get some differences between observed rainfall values and estimated rainfall values. When considering about F test values Spline interpolation method can be identified as the most suitable for rainfall analysis in Sri Lanka. Other method were in accepted area but in some years those are not accepted. The Spline method was accepted for all analysis in annual as well as monthly.

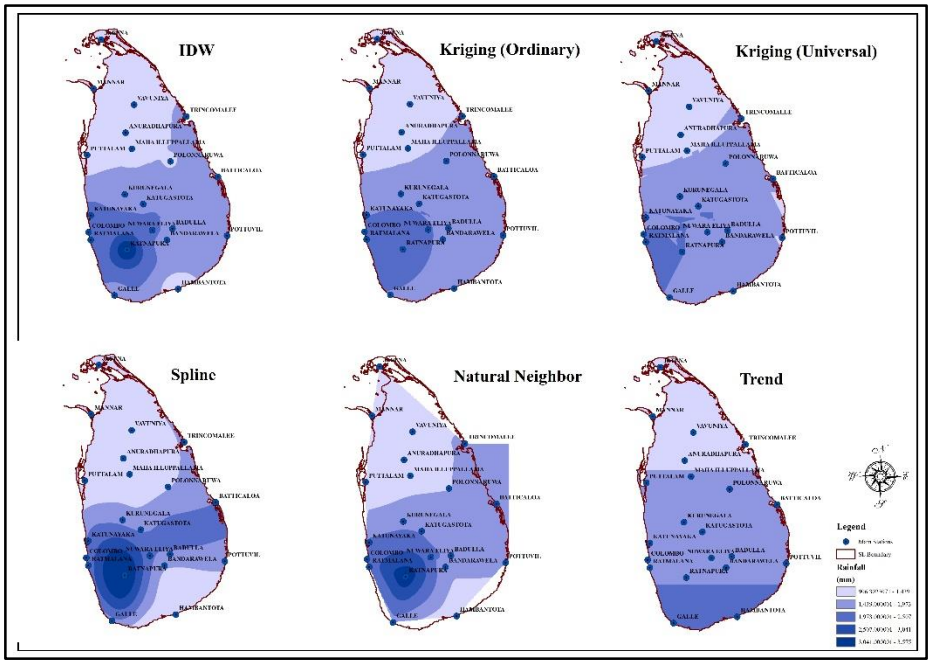

Figure 6: Different Rainfall Surfaces in 2013

According to the scatter plot analysis Spline also show strong positive association. However, according to the all scatter plots, one station have shown as outlier because the actual observed rainfall shown it is as extreme values from the others. So it have shown as high difference. However, Spline method shown R value as 0.62 and others show low values. Therefore, the Spline method was found to have the greatest efficiency of all five method.

CONCLUSION

In this study, five different Interpolation methods were compared using rainfall data in Sri Lanka. Therefore, the rainfall estimation accuracy has been analyzed in detail.

When comparing rainfall surfaces IDW, Kriging and Spline were shown some similarity of their distribution pattern. However, Trend and Nearest Neighbor were shown more different distribution pattern than the others. Extracted estimated values also shown some differences and Spline, Kriging and IDW were indicated minimum variance between estimated values and the actual rainfall values. However, the highest accuracy can be identified in Spline. According to the F test Spline, Kriging and IDW in an accepted area and Spline shown lowest F value and best accuracy for rainfall surfaces. Sometimes (monthly rainfall data analysis) Nearest Neighbor interpolation method has been shown as accepted but it was not for the all analysis and also cannot identified as a good accuracy. Also Trend interpolation method was rejected at all time and it is not a suitable interpolation method for rainfall analysis in Sri Lanka.

Therefore, finally the study was identified as the Spline method is very accurate and suitable method for create rainfall surfaces in Sri Lanka. Also it can be used to both monthly and as well as annual rainfall data analysis.

However, the study has faced some barriers with rainfall data because some data were indicated as missing rainfall data. Therefore those data cannot analyze and it will be given incorrect result. So in this study was revealed that rainfall data must be accurate and also it must be well distributed over the study area. It will be given best accurate result for the study.

Interpolation is the best spatial analysis tool in ArcGIS and it is very useful for creating surfaces. However, we should be selected very best method for our analysis.

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