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ASSESSMENT OF THE CHANGES OF CLIMATE IN BANGLADESH USING GEO-SPATIAL INTERPOLATION OF CLIMATIC VARIABLES

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ABSTRACT: Bangladesh is a developing country with limited resources where global warming and subsequent climate change is a serious issue. So, the present climatic condition and its changes are important knowledge to influence policy making and adaptation strategies. This study has focused on analysis of daily maximum and minimum temperature and daily rainfall from 1951 to 2010 for the pre-monsoon, monsoon, post-monsoon and dry season. Required climate data were obtained from Bangladesh Meteorological Department (BMD) and QGIS was used as a tool for the analysis. The data were interpolated using some geo-spatial interpolation techniques namely; Inverse Distance Weighted (IDW), Kriging and Local Polynomial Interpolation, where the Kriging method has shown minimum Root Mean Square Error (RMSE) proving its suitability to determine changes in climatic parameters. Spatial interpolation by Kriging has shown increase in maximum temperature mostly in the pre-monsoon and monsoon season up to 2.94 ºC. Minimum temperature has decreased up to 2 ºC in the pre-monsoon season. Also, shifting in daily rainfall pattern showed increased monsoon rainfall up to 10-12 mm and decreased dry season rainfall up to 8 mm. All these changes were higher in the last 20 years which gives the evidence of climate change in Bangladesh.

Keywords: *climate change, geo-spatial interpolation, IDW, Kriging, Local Polynomial Interpolation.*

1. Introduction

Climate is a measure of variation pattern in different weather parameters such as temperature, precipitation, wind speed, humidity, sunshine hour, solar radiation, etc., in a given region over long periods of time, usually 30 years or more. Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years occurring due to natural or human induced activities. According to IPCC, "Climate change is a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2007). Increased emission of greenhouse gases has caused global warming and consequent sea level rise due to higher atmospheric temperature. The impact of climate change is becoming severe day by day to the world and Bangladesh is not out of its purview. Bangladesh is a small deltaic country in the Ganges-Brahmaputra-Meghna basin, where its available resources are continuously being exploited to meet the demand of the growing population. Though this country hardly contributes to the causes of the changing climate, its impact is more severe here than on the other developed countries of the world. With the limited resources and opportunities, it is not possible for the country to mitigate the impacts of climate change, rather than to adapt with the changing conditions. Almost two-third of the people depends on agriculture for their living (World Bank, 2000) and cultivation of agricultural crops ensure the food security of the country. Climate change poses severe threat mostly to the agricultural sector and food security among all other affected sectors (Sikder, 2010). So, the

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knowledge of the present climatic condition, the changes and its impact on different sectors is very much important for policy making, planning and management strategies to cope up with the severity of climate change in Bangladesh. A Geographic Information System (GIS) tool can assist in monitoring the changes in climatic parameters and provide the knowledge of changed climate of a region. A Geographic Information System is a computer system that helps to visualize, question, analyze, and interpret data to understand relationships, patterns, and trends. This study has focused on the use of a mapping tool, QGIS, to determine the changes in three important climatic parameters namely, maximum temperature, minimum temperature and rainfall for a period of 1951 to 2010 using a statistical distribution method. This study has also determined the most suitable geo-spatial interpolation technique which can be used to monitor the changes in climatic parameters in an efficient way. The outputs from this study can contribute in alerting the planners and policy makers to develop certain adaptation strategies against climate change.

2. Materials and Methods

2.1. Data collection

For the above study, required climate data were obtained for three different parameters: daily maximum and minimum temperature and daily rainfall of different climate stations of Bangladesh from Bangladesh Meteorological Department (BMD) for 60 consecutive years starting from 1951 up to 2010. The 60 years climate data were classified in three 20 years period: 1951-1970, 1971-1990 and 1991-2010 for four different seasons which are, pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and dry season (December-February). The daily temperature and rainfall data were processed as seasonal average for the three periods and incorporated in QGIS for geo-spatial interpolation using different methods.

2.2. QGIS

Quantum GIS (QGIS) is an open source Geographic Information System that provides data viewing, editing and analysis capabilities. It helps to input, store, retrieve, manipulate, analyze and output geographically referenced data and to interpret maps using different tools in order to support decision making for planning and management strategies. It can be used for spatial interpolation of different climate variables using the different tools available in spatial analyst toolbox. Various studies have been performed using QGIS tool for interpolation of different climatic variables (Celik, 2003; Ramachandra and Shruthi, 2005; Nguyen and Pearce, 2010). This study has used three different geo-spatial interpolation techniques from the toolbox to determine the most suitable method. These methods are: Inverse Distance Weighted (IDW), Simple Kriging and Local Polynomial.

2.2.1. Inverse Distance Weighted (IDW) method

Inverse Distance Weighted (IDW) is a geo-spatial interpolation method in GIS toolbox. It is a simple and intuitive deterministic interpolation technique based on a principle that sample values closer to the prediction location having more influence on prediction value than sample values further apart (Ranade, 2013). It uses a sample set of point locations to create a raster surface based on the data's attribute values (Chandel et al., 2013).

2.2.2. Kriging method

Kriging is a generic name for a family of least-squares linear regression algorithms that are used to estimate the value of a continuous attribute at any unsampled location using only attribute data available (Lo and Yeung, 2002). It is an improvement over IDW method because prediction estimates tend to be less biased and also predictions are accompanied by prediction standard errors (Ranade, 2013). Kriging treats the continuous attribute to be interpolated as a regionalized variable (Lo and Yeung, 2002).

2.2.3. Local Polynomial interpolation

Local Polynomial interpolation is the local interpolation technique of a given data set by using polynomial. This interpolation method fits many polynomials, each within specified overlapping neighborhoods. The search neighborhood can be defined using the search neighborhood dialog of the interpolation window.

The collected climate data were analyzed using these interpolation techniques to determine which method shows the lowest RMSE value. Then that method was selected for the geo-spatial interpolation to determine the changes in temperature and rainfall. The climate data were overlaid on the district shape file of Bangladesh to show the interpolated data over the country. For each 20 years duration i.e. for 1951-1970, 1971-1990 and 1991-2010, temperature and rainfall data for each of the four seasons were interpolated to obtain images. Then using the 'Raster Calculator' tool from the spatial analyst toolbar, the difference between interpolated values of two images was obtained through Structured Query Language (SQL). These differences showed the increase or decrease in the temperature and rainfall within the periods for each season from which the decision about changes in climate were made.

3. Results and Discussion

From the analysis of three geo-spatial methods mentioned above, the Root Mean Square Error (RMSE) value of three methods for interpolation process are compared and provided in the following Table 1. It was found that for interpolation of both temperature and rainfall data the RMSE value of Kriging method was the lowest among the three. This proved the suitability of this method for interpolation of climate data and the year to year comparison.

Table 1: Root Mean Square Error Value of three interpolation method

Climate parameter	Season	Duration	Methods		
			IDW	Kriging	Local polynomial
Maximum temperature	Pre-monsoon	1951-70	0.85	**0.81**	0.89
		1971-90	0.69	**0.65**	0.66
		1991-2010	1.35	**1.05**	1.25
	Monsoon	1951-70	0.56	**0.50**	0.51
		1971-90	0.42	**0.38**	0.43
		1991-2010	0.75	**0.71**	0.73
	Post-monsoon	1951-70	0.34	**0.31**	0.33
		1971-90	0.27	**0.25**	0.26
		1991-2010	0.40	**0.38**	0.39
	Dry season	1951-70	0.53	**0.49**	0.55
		1971-90	0.36	**0.33**	0.35
		1991-2010	0.89	**0.81**	0.86
Minimum temperature	Pre-monsoon	1951-70	1.19	**1.04**	1.07
		1971-90	1.23	**1.18**	1.24
		1991-2010	1.02	**0.84**	0.86
	Monsoon	1951-70	0.44	**0.43**	0.38
		1971-90	0.33	**0.31**	0.28
		1991-2010	0.31	**0.32**	0.20
	Post-monsoon	1951-70	1.18	**1.04**	1.12
		1971-90	1.15	**1.08**	1.10
		1991-2010	1.15	**0.98**	1.03
	Dry season	1951-70	2.01	**1.77**	1.83
		1971-90	1.79	**1.55**	1.59
		1991-2010	1.72	**1.46**	1.52

Table 1: Root Mean Square Error Value of three interpolation method (continued)

Climate parameter	Season	Duration	Methods		
			IDW	Kriging	Local polynomial
Rainfall	Pre-monsoon	1951-70	2.18	**1.38**	1.42
		1971-90	1.65	**1.21**	1.55
		1991-2010	1.90	**1.63**	1.71
	Monsoon	1951-70	4.57	**3.87**	4.02
		1971-90	5.36	**3.67**	4.89
		1991-2010	5.63	**3.80**	3.95
	Post-monsoon	1951-70	0.48	**0.44**	0.47
		1971-90	0.80	**0.69**	0.73
		1991-2010	0.40	**0.36**	0.38
	Dry season	1951-70	0.45	**035**	0.39
		1971-90	0.07	**0.03**	0.09
		1991-2010	0.02	**0.01**	0.03

From the above table it can be stated that, among the three interpolation techniques, the Kriging method showed the lowest RMSE values. So, this method was proved to be the most suitable interpolation technique and was selected for preparing the interpolated image of temperature and rainfall values of different stations of Bangladesh.

The interpolated images created using the Kriging method for three twenty years' classes of four different seasons were compared by raster calculator tool. The difference of interpolated values from 1951-1970 to 1971-1990 and from 1971-1990 to 1991-2010 were obtained for each season and each parameter. The differences showed that the maximum temperature has increased up to 2.94 ºC during the pre-monsoon season and up to 2.44 ºC during the monsoon season as shown in Figure 1. The increase in temperature was higher from the 1971-1990 to 1991-2010, that is during the last 20-30 years, than it was in early period. The minimum temperature also decreased up to 1.24 ºC during the dry season and 2.05 ºC as shown in Figure 2 in the pre-monsoon season during the period of 1971-1990 to 1991-2010 with a higher rate of decrease than the years before that. The changes are shown in Table 2 below:

Table 2: Changes in values of climate parameters

Season	Duration	Increase in maximum temperature (ºC)	Decrease in maximum temperature (ºC)	Changes in rainfall (mm)
Pre-monsoon	1951-70 to 1971-90	1.91	2.05	1.13 (increase)
	1971-10 to 1991-2010	2.94	1.06	2.69 (increase)
Monsoon	1951-70 to 1971-90	0.60	1.02	6.42 (increase)
	1971-90 to 1991-2010	2.44	0.68	11.44 (increase)
Post-monsoon	1951-70 to 1971-90	0.34	0.39	1.16 (decrease)
	1971-90 to 1991-2010	1.24	0.72	3.35 (decrease)
Dry season	1951-70 to 1971-90	0.91	0.81	2.35 (decrease)
	1971-90 to 1991-2010	1.68	1.24	7.92 (decrease)

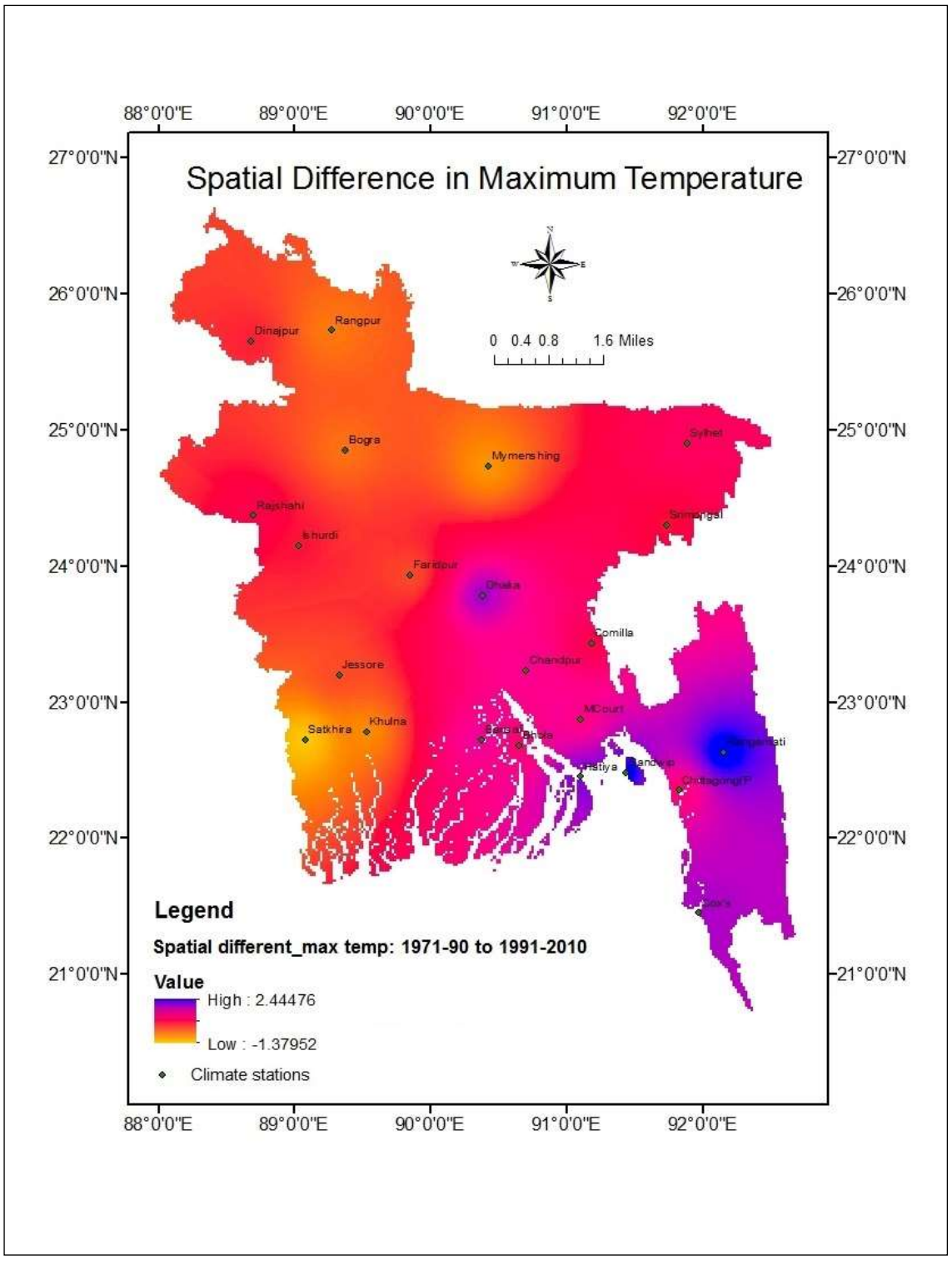

Figure 1: Increase in maximum temperature during monsoon from 1971-1990 to 1991-2010

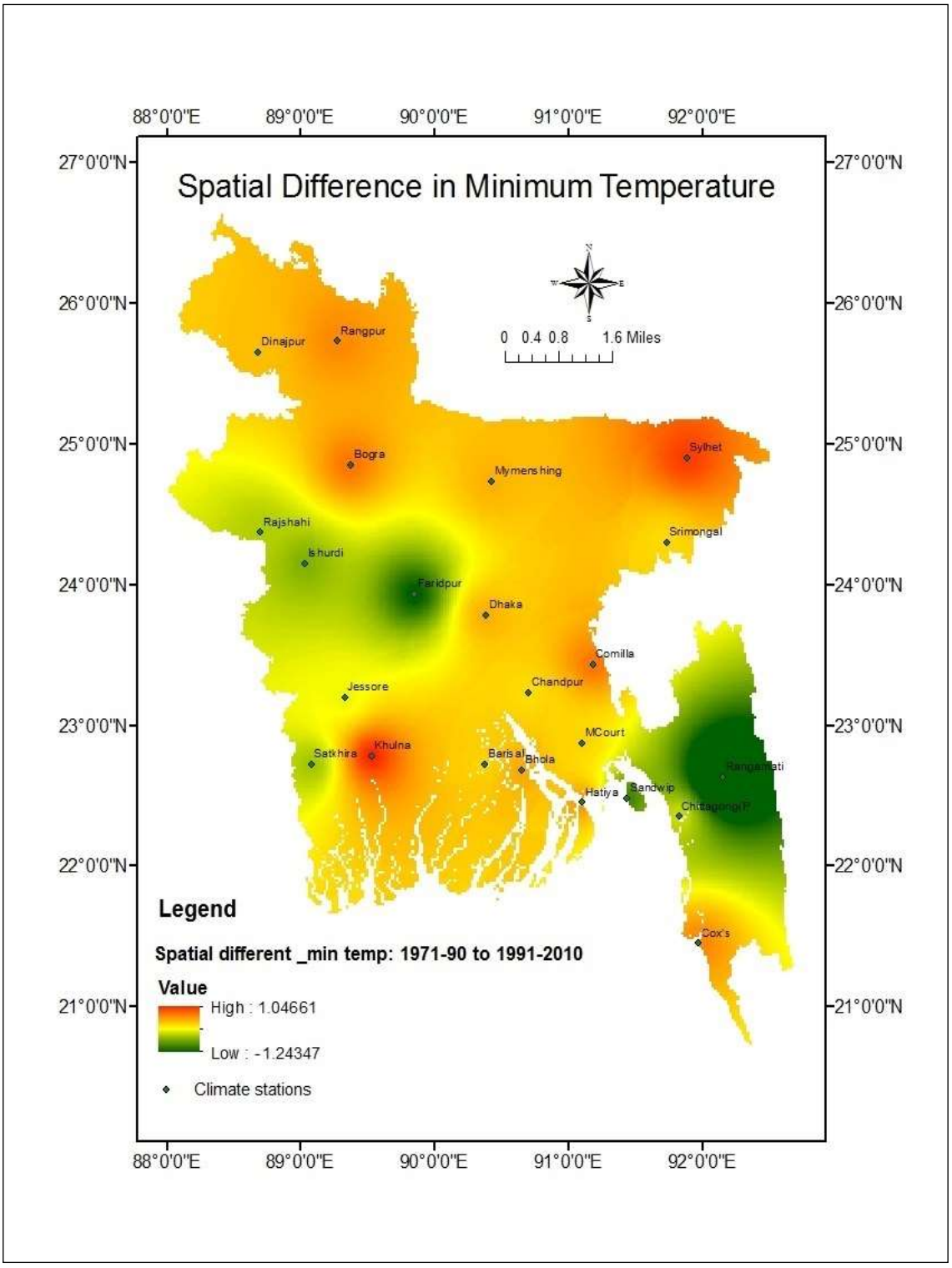

Figure 2: Decrease in minimum temperature during the dry season from 1971-1990 to 1991-2010

These values indicate the increasing trend of maximum temperature and decreasing trend of minimum temperature mostly in the last two decades. Also, the rainfall pattern followed the trend of increase in monsoon rainfall of about 12 mm and decrease in dry season rainfall of about 8 mm as shown in Figure 3. The changes were higher in the last 20-30 years i.e. from the 1971-

1990 to 1991-2010 duration as it was for the temperature variable. Value of changes may vary depending on the selected interpolation technique. The changes in both temperature and rainfall values provide the evidence of changed climate over the last several years where considerable increase and decrease of climate variables were observed supporting the known trend of present climate.

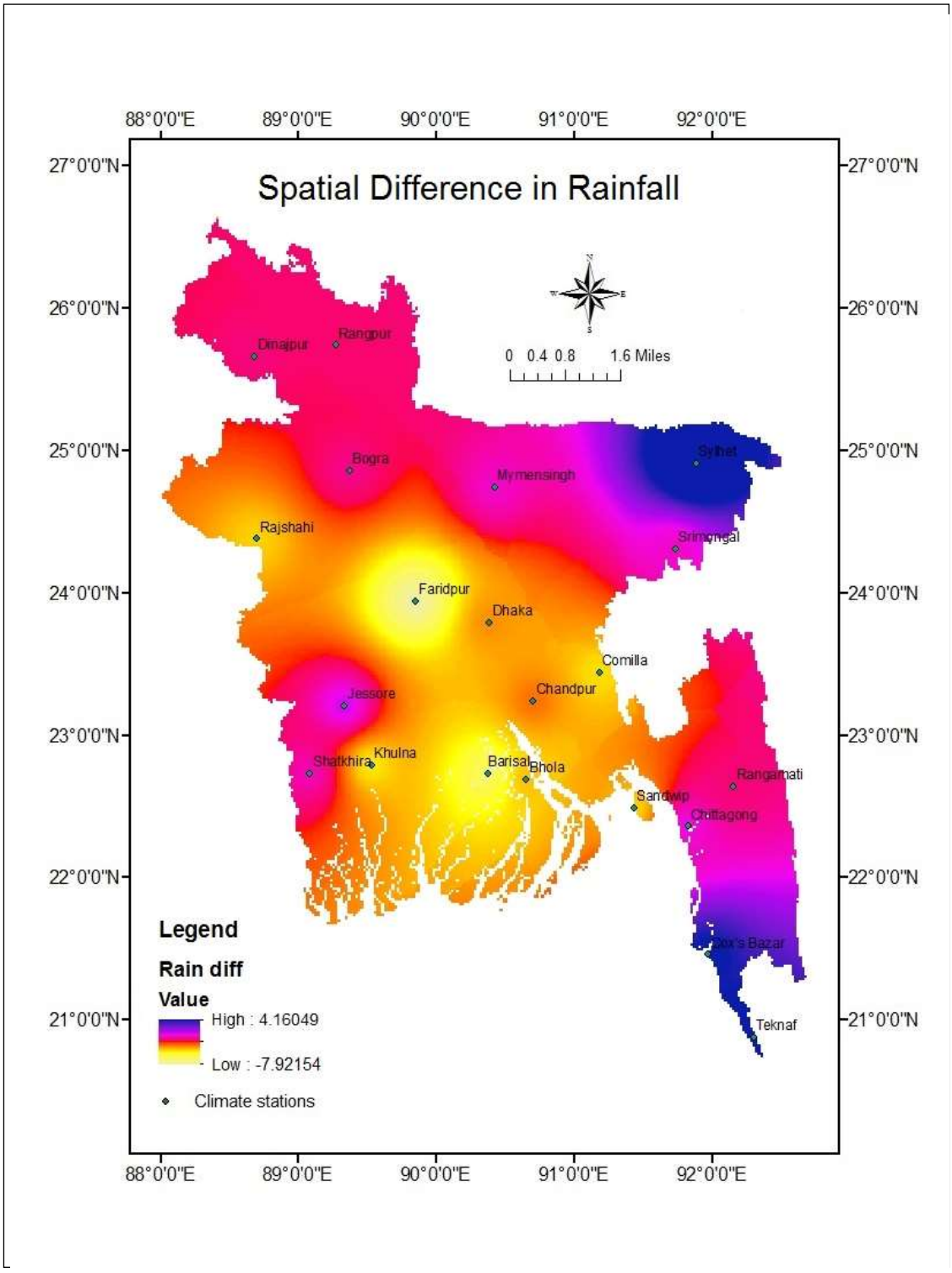

Figure 3: Decrease in rainfall during the dry season from 1971-1990 to 1991-2010

3. Conclusion

In the study, analysis performed on the temperature and rainfall variables, the most suitable geo-spatial interpolation method was found to be the Kriging method. Using Kriging, the interpolation of temperature and rainfall data were performed where considerable changes observed in the last two decades. The maximum and minimum temperature were both observed to be increased and decreased respectively giving the evidence of climate change. Increase in monsoon rainfall and decrease in the dry season rainfall also supported the trend of wetter summer and drier winter. The results of the study may assist in selecting the suitable method of interpolation which can be used for analyzing the climate variables in Bangladesh among the long range of available tools. This can save time of the user and provide better understanding. Also the observed changes in temperature and rainfall have indicated that, climate is actually changing in this country. The impact of climate change will bring heavy damages to different sectors causing a lot of sufferings. So, proper adaptation strategies and planning are required to be taken using the knowledge so that the country can survive through the long suspected devastation of climate change phenomenon.

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