PRECIPITATION DATA INTERPOLATION FOR METEOROLOGICAL DROUGHT MAPPING IN PAKISTAN

N. Mazhar and M. Nawaz*

Department of Geography, Lahore College for Women University, Lahore, Pakistan
*Research Institute of Environment and Livelihoods, Charles Darwin University, Australia
Corresponding Author: noshmazhar@gmail.com

ABSTRACT: Drought had been observed as a recurrent disaster which gradually becomes a usual phenomenon of a region. Severe environmental, economic and social impacts for the victims had been seen. Adverse impact of meteorological drought could be curtailed to a minimum only through proper planning and drought mitigation measures. This research study offered comparison of three interpolation methods which were used to create meteorological drought intensity surfaces. This study delineated the pattern of meteorological drought intensity in Pakistan during1980-2010. Three maps were developed using three different interpolation methods and specific semivariograms. It was concluded that the Spline method using tension semivariogram presented meteorological drought picture for Pakistan, which appeared to be much closer to the classification of droughts given by the government of Pakistan for the drought 2000-01.

Key words: Interpolation, semivariogram, meteorological drought, aridity.

INTRODUCTION

The term drought is defined by World Meteorological Organization (WMO), as "a sustained, extended deficiency in precipitation." Drought is often termed as a creeping disaster, since unlike earthquakes or cyclones, it takes a longer time to develop and its impacts may get prolonged (Anjum et al., 2012). In a study (Monacelli et al., 2005) mention that an operational definition of meteorological drought can be given on the "basis of the degree of dryness and the duration of the dry period" and the definition of this type of drought varies from region to region. Aridity is the hallmark of Pakistan's climate. Being arid it remains a frequent victim of droughts. Two to three years out of every ten years in Pakistan, are drought years. The worst drought for central and south-west Asia, including Pakistan, was during 1999-2000, (Mishra and Singh, 2010). In this episode Pakistan, Afghanistan, Iran, Tajikistan, Uzbekistan and Turkmenistan suffered a lot. On an average in Pakistan there is 20-30mm of rain per month, however at the foothills of Himalayas it is 200 mm. Maximum rain fall is in the monsoon season, i.e. from July till September. The tail end of the western disturbances reach Pakistan in winter and becomes the cause of winter rains (Mc Sweeney et al., 2010).

Mean annual rainfall in Pakistan is highly variable. Figure-1 presents the average annual rainfall of Pakistan for the period from 1985-2012. The graph shows steepest decline in the annual mean precipitation during 1999-2002, and 2008-2009, both of which were drought episodes for Pakistan.

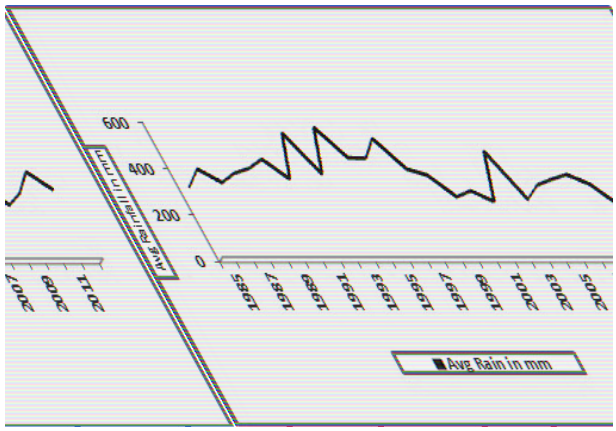

Fig-1: Showing average annual rainfall, from 1985-2012 (Pakistan Meteorological Department)

Pakistan has vulnerable environments and has recurrently been affected by meteorological droughts due to lack of contingency planning. Since drought has great spatial and temporal variability thus large scale mapping and monitoring must be carried out. Through this the government can have an effective decision support system, (Anjum et al., 2012).

In south Asia water resource management is a critical issue. To solve this problem the regional drought may be properly monitored, only then appropriate water resource management is possible, (Hisdal and Tallaksen 2003). Drought monitoring can play a pivotal role in drought risk management. Therefore maps are an essential tool for proper monitoring of spatial distribution of drought intensity (Akhtari et al., 2009).

Drought Mapping: Drought Management Centre for Southeastern Europe (DMCSE) uses spline with tension

semivariogram for drought mapping, as it tunes the stiffness of the interpolant according to the character of the modeled phenomena. (Ali et al., 2011), also reported that Spline can be mathematically elegant model that can be used for surface estimation.

However, it is a fact that IDW and Kriging methods of interpolation have also been used in international research for the mapping of drought indices. In a study (Nohegar et al., 2013) also concluded that Kriging was the best method for spatial analysis of drought indices.

IDW is the most appropriate interpolation technique that helps in giving an impression that the variables being presented share common characteristics and are close to one another (Patel and Chopra, 2007). IDW for drought mapping is practiced on the assumption that rainfall for any area is interpolated using the weights that are calculated on the base of distance between each rain gauge and the desired location. Inverse Distance Weighted (IDW) helps in creating a smooth surface of mean rainfall with its meaningful troughs and peaks.

IDW interpolation method is used for mapping the drought indices of Carolinas (Rhee, 2007). This method is used as the main limitation of study is sparse distribution of weather stations. Thus, in order to better represent the drought conditions of the Carolinas, IDW technique is used in which information from nearby weather stations is utilized to generate a smooth surface

MATERIALS AND METHODS

The study was carried out during the period from 1980-2010. Precipitation data was acquired from Pakistan Meteorological Department for 34 districts. Annual average of the precipitation for each station was calculated in Microsoft Excel. Once the attribute table was ready in Arc GIS 9.0, then a comparison of three interpolation methods was carried out in order to find the best method of interpolation that created the most reliable meteorological drought intensity surface. The Spline method of interpolation with tension semivariogram, was the best to depict the drought intensity pattern of Pakistan, as it presented similar picture of drought intensity classes as presented in the government classification of droughts for the year 2000-01 (FAO, 2001). The other method of interpolation used to generate drought intensity surface was Inverse Distance Weighted (IDW) and Kriging with Gaussian semivariogram (Figure-2 and 3).

RESULTS AND DISCUSSIONS

The limitation of this study was the unavailability of rainfall data for most of the districts of Pakistan. Mean annual rainfall data was available for only 34 districts, thus a very scattered drought intensity impact was conveyed through the map. To overcome this limitation, drought intensity surface was created using the method of interpolation in Arc GIS 9.0. Since there were different interpolation methods with different semivariogram models available in this software, thus using all the three interpolation methods and specific semivariogram models three maps as presented in figure-2, 3 and 4 were prepared which showed drought intensity surfaces. They also showed some changes in drought intensity pattern. The most perfectly representative drought pattern of our country was shown through Spline method. The government classification of drought for 2000-01 in Pakistan, has been presented in the study conducted by (FAO, 2001) which was correlated with the classification of the meteorological drought stricken districts of Pakistan i.e. Chagai, Quetta, Pishin, Kharan, D.G. Khan, Bhakkar, Kohat, Jhelum, Khushab, Chakwal, Mianwali, Attock which fell under the category of severe drought of government classification (FAO, 2001). In the present study these districts fell under the category of exceptional, extreme and severe droughts. Most of the districts at the foothill of Himalayas fell under the category of least drought according to government classification (FAO, 2001) and minor drought according to the classification of this study. Since Spline method presented the meteorological drought picture similar to the government classification of drought for 2000-01 (FAO, 2001) thus spline method was the best method for mapping meteorological drought intensity for Pakistan.

The comparison of different interpolation methods for mapping droughts has been done by various researchers (Attorre et al., 2007, Ali et al., 2011 and Nohegar et al., 2013). Kriging and Spline interpolation methods for drought mapping were used by (Akhtari et al., 2009) and the authors concluded that Kriging was the best method for drought mapping in Tehran, a province of Iran.

Figure-2, 3 and 4 were drawn using three methods of interpolation. Figure-2 was drawn using IDW method. Figure-3 showed the map drawn using Kriging method with Gaussian semivariogram, while figure-4 was drawn using Spline method, Tension semivariogram which was the most suitable one to present the drought situation of Pakistan. Figure-2 showed entire Balochistan and Sindh in the grip of exceptional drought for the period from 1980-2010. However, there was a pocket of extreme drought encircling Barkhan. Southern and central Punjab, southern Khyber Pakhtoon Khawa and a small pocket of land in the northern areas of Pakistan was also in the grip of exceptional drought. However there was a marked decrease of areas affected by exceptional drought in the map which was drawn by using Kriging method. In figure-3 entire Balochistan and Sindh, along with southern Punjab were shown to be affected by exceptional drought. While northern Punjab, northern

areas of Pakistan and northern Khyber Pakhtooon Khawa areas are shown to be affected by minor drought (figure-3).

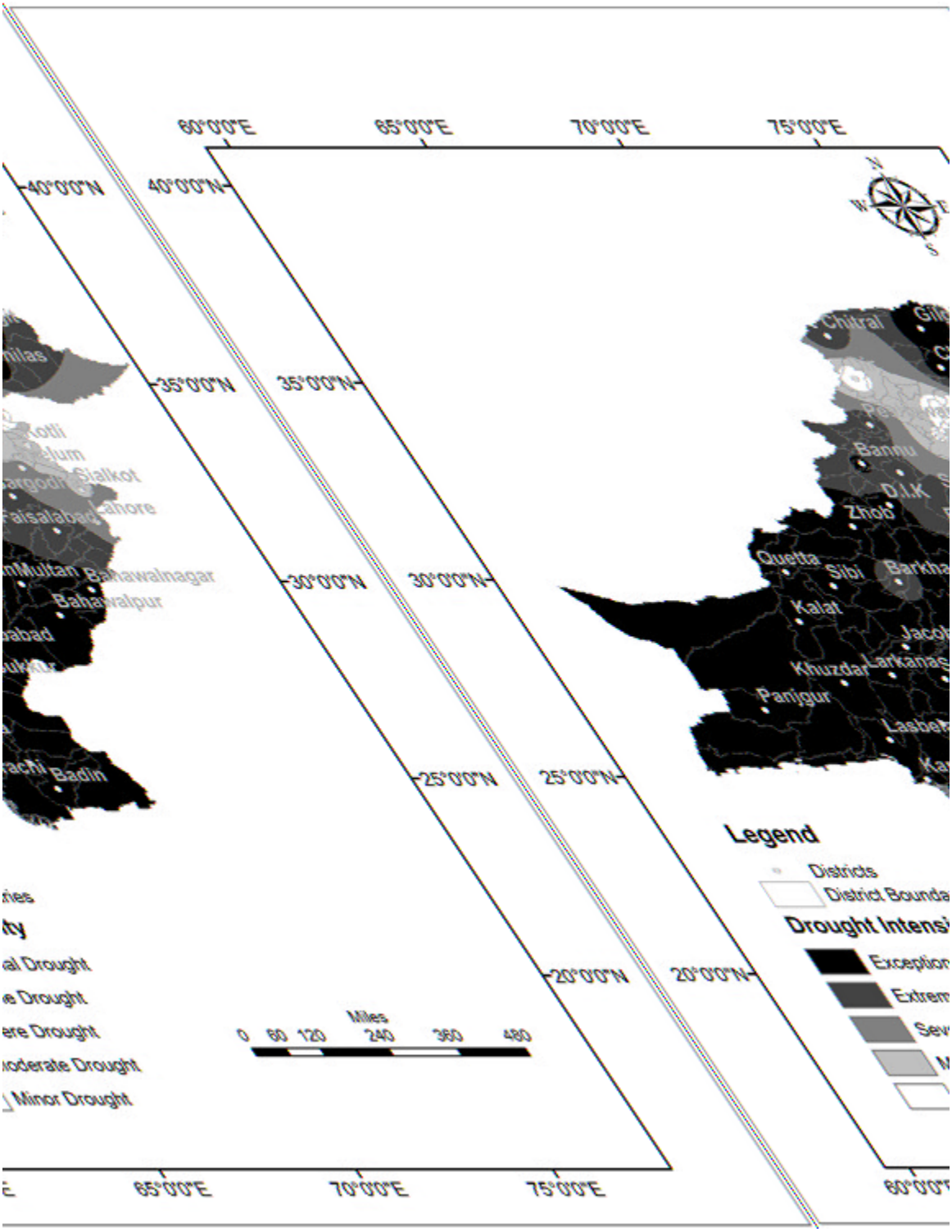

Fig-2: Meteorological drought intensity in Pakistan- IDW Interpolation, 1980-2010

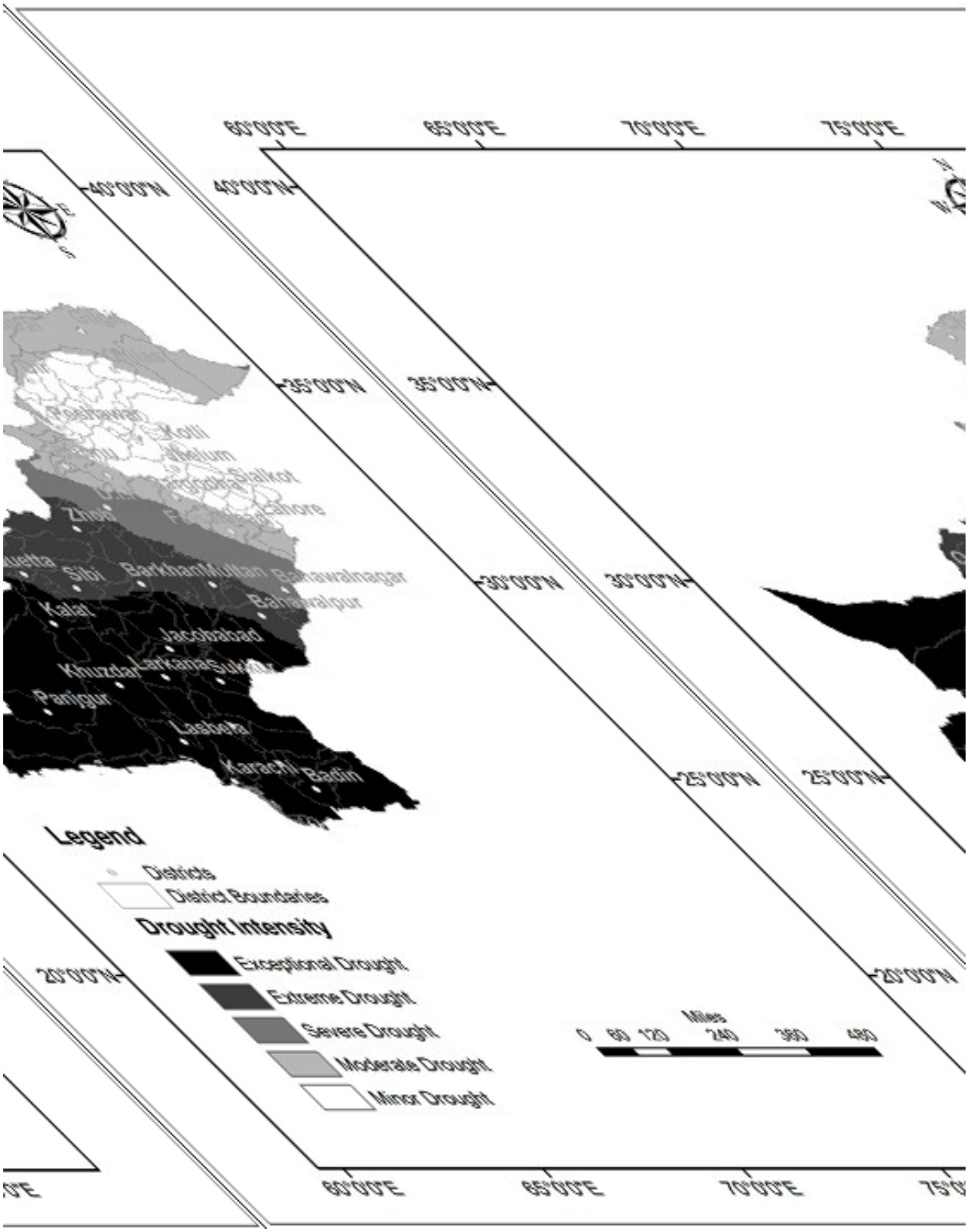

Fig-3: Meteorological drought intensity in Pakistan- Kriging (Gaussian) Interpolation, 1980-2010

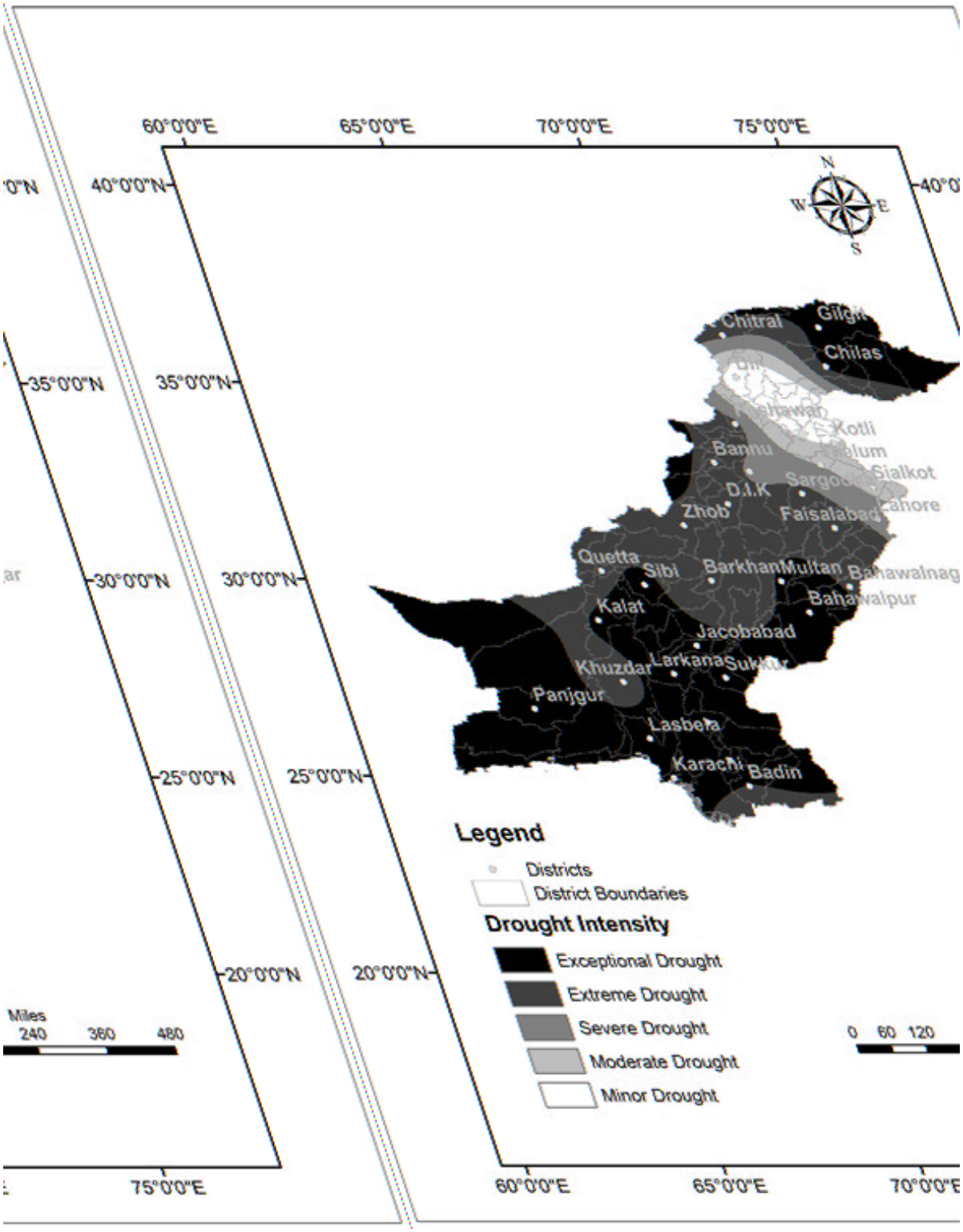

Fig-4: Meteorological drought Intensity in Pakistan- Spline (Tension) Interpolation, 1980-2010

This may not be a correct picture since it is well known that the annual precipitation received in the north western regions of Pakistan, i.e. Gilgit and Chitral districts is meagre as they receive almost the tail end of the western disturbances and monsoons and thus become a frequent victim of meteorological droughts. Therefore Kriging method of interpolation was not suitable in case of drought mapping in Pakistan. Figure-4 presented the

drought intensity surface generated by Spline method using tension semivariogram. This method used delicate curves to represent the picture of meteorological droughts in Pakistan which appeared to be the most close to reality. Figure-4 showed western, south-western and north-eastern Balochistan and almost entire Sindh, except the southern strip, southern Punjab that engulfs Bahawalpur, Bahawalnagar and Multan districts and extreme northern strip of Pakistan to be suffering from exceptional drought.

Barkhan region in this map also appeared to be experiencing extreme drought just as the map using IDW had shown. Thus the credibility of Spline method could further be affirmed. Drought Management Centre for Southeastern Europe (DMCSE) also incorporated the Spline method of interpolation for drought mapping. The results of this study are consistent with the results achieved by (Anjum et al., 2010 and Anjum et al., 2012); Sindh and Balochistan provinces lie in hyper arid climatic region and thus are most vulnerable to droughts. (Hussain et al., 2004), has also concluded that the water table in both the severely affected provinces has declined considerably due to frequent droughts and over exploitation of groundwater.

Conclusion: The maps presented in this study are helpful in indicating the most drought affected zones of Pakistan. From these maps it can be identified that besides Baluchistan and Sindh, which are known to be recurrently drought-hit provinces, drought impacts have also penetrated into Punjab and Khyber Pakhtoon Khawa provinces. However severity of meteorological droughts in Sindh and Balochistan is a matter of concern. Amongst the three interpolation methods used in Figures-2, 3 and 4 for creating meteorological drought intensity surfaces, Spline method provided the most accurate picture of the country. The exceptional drought pocket shown in Figure-4, is an eye opener for the policy makers, as the creeping hazard is now taking our northern areas in its grip. Thus, in this study it can be concluded that the most near to reality, meteorological drought intensity is presented by the Spline method.

Acknowledgements: The author would like to acknowledge and thank the selfless support and guidance of her Father, Mother, Husband, Father and Mother in law and Ms. Zaynah Sohail.

REFERENCES

Akhtari, R., S. Mori, M. H. Mahdian and V. Smakhtin. Assessment of areal interpolation methods for spatial analysis of SPI and EDI drought indices. International Journal of Climatology, 29(1): 135-145 (2009).

Ali, M. G., K. Younes, A. Esmaeil and T. Fatemeh. Assessment of Geostatistical Methods for Spatial Analysis of SPI and EDI Drought Indices. World Applied Sciences Journal, 15(4): 474-482 (2011).

Anjum, S. A., M. F. Saleem, M. A. Cheema, M. F. Bilal and T. Khaliq. An Assessment to Vulnerability, Extent, Characteristics and Severity of Drought Hazard in Pakistan. Pakistan Journal of Science, 64(2): (2012).

Anjum, S. A., L. C. Wang, J. Salhab, I. Khan and M. F. Saleem. An assessment of drought extent and impacts in agriculture sector in Pakistan. Journal of Food, Agriculture & Environment, 8(3&4): 13-59 (2010).

Attorre, F., M. Alfo, M. De Sanctis, F. Francesconi and F. Bruno. Comparison of interpolation methods for mapping climatic and bioclimatic variables at regional scale. International Journal of Climatology, 27(13): 1825-1843 (2007).

FAO/WFP. Crop and food supply assessment mission to Pakistan (2001).

Hisdal, H. and L. M. Tallaksen. Estimation of regional meteorological and hydrological drought characteristics: a case study for Denmark. Journal of Hydrology 281(3): 230-247(2003).

Hussain, Z., A. S. Qureshi, R. Majeed and M. Saleem. Drought mitigation in Pakistan: current status and options for future strategies. International Water Management Institute (2004).

Mc Sweeney C., G. Lizcano, M. New and X. Lu. The UNDP Climate Change Country Profiles: Improving the accessibility of observed and projected climate information for studies of climate change in developing countries. Bulletin of the American Meteorological Society 91(2): 157-166 (2010).

Mishra, A. K. and V. P. Singh. A review of drought concepts. Journal of Hydrology, 391(1): 202-216 (2010).

Monacelli, G., M. C. Galluccio and M. Abbafati. Drought assessment and forecasting. Drought within the context of the region VI (2005).

Nohegar, A., M. Heydarzadeh and A. Malekian. Assessment of Severity of Droughts Using Geostatistics Method (Case Study: Southern Iran). Desert, 18(1): 79-87(2013).

Patel, N. R., P. Chopra and V. K. Dadhwal. Analyzing spatial patterns of meteorological drought using standardized precipitation index. Meteorological Applications, 14(4): 329-336 (2007).

Rhee, J. A Regional Drought Monitoring System for the Carolinas, Pro Quest (2007).