# Spatial Interpolation of Rainfall in Iraq

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**Abstract**

Several methodologies exist for spatial interpolation of climate and weather parameters, among them is the inverse distance weighting. In this paper, the Inverse Distance Weighting (IDW) method was used to estimate the rainfall distribution in Iraq. The relationship between interpolation accuracy and two critical parameters of IDW were evaluated: these were power and a radius of influence (search radius). A total of 24 rainfall stations and rainfall data between 2003 and 2013 were used in this paper. Real data, obtained from Iraqi Meteorological Organization and Seismology, are used for evaluation. The results showed that these parameters have a great effect on the produced rainfall maps. The maps are produced for p= 1.5 and p=2.0 and were having profound effect of smoothing. The results present samples of maps for months January, October, and December for the years 2004, 2012, and 2013 within the period of the data.

**Keywords.** GIS, Inverse Distance Weighted, Iraq and Rainfall Interpolation.

## ألاستنباط المكاني للأمطار في العراق

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الخلاصة

توجد عدة طرق للاستنباط المكاني للمناخ و لعناصر الجو ، ومن بينها وزن معكوس المسافة. في هذا البحث، استخدمت طريقة وزن معكوس المسافة لتقدير توزيع الأمطار في العراق. تم حساب العلاقة بين دقة الاستنباط وعنصرين أساسيين لطريقة وزن معكوس المسافة وهما ألاس ونصف قطر التأثير( نصف قطر البحث). في هذا البحث تم استخدام بيانات 24 محطة لقياس الأمطار وبيانات للفترة من 2003 و لغاية 2013. تم الحصول على البيانات الفعلية من الهيئة العامة للأنواء الجوية و الرصد الزلزالي واستخدمت لأغراض الحساب. أثبتت النتائج بان هذه العوامل كان لها التاثير الواضح على الخرائط المنتجة. تم انتاج الخرائط لقيم المتغير P عند 1.5 و 2 و كان التاثير واضح في التنعيم. تم عرض النتائج للاشهر كانون الثاني ، تشرين الاول و كانون الاول للسنين 2004 ، 2012 و 2013 ضمن فترة البيانات.

**الكلمات المفتاحية:** نظم المعلومات الجغرافية، وزن معكوس المسافة، العراق واستنباط الأمطار.

## Introduction

It is important to understand the spatial and temporal patterns of rainfall and their variability in order to gain knowledge about the balance of water dynamics for water resources management, and to plan strategies for solving many problems such as predicting natural hazards caused by heavy rain*(Shoji, and Kitaura, 2006*). Accurate information about the climatic conditions of a region is indispensable for optimal management of agriculture, environment and related activities. Meteorological data coming from stations are the most reliable and used sources to assess the climate condition of an area*(Ozelkan, 2011*).Geographic Information System (GIS) is a tool to acquire, store and process spatial data .Spatial interpolation of measurements from various meteorological stations is widely used to approximate a real meteorological parameters. In this paper we used a deterministic method in the spatial analyst called Inverse Distance Weighting (IDW) that aims to estimate values at unknown weather station by using known measurements and the continues surface data can be interpolated from the isolated point data .As stated by many researchers, useful methods of rainfall analysis are based on techniques of spatial analysis and interpolation using information collected from rain gauges in relevant areas(*Goovaerts, 2000*),Among all the meteorological and hydrological parameters, rainfall is the most difficult to predict due to its inherent variability in time and space(Bargaoui, 2009).This paper based on monthly rainfall data were collected from meteorological stations distributed across the country and digitally encoded into a GIS database using IDW method. Inverse distance weighting interpolation is a deterministic estimation method where values at unsampled points are determined by a linear combination of values at known sampled points. The degree of influence, or the weight, is expressed by the inverse of the distance between points raised to a power. A power of 1.0 means a constant rate of change in value between points, and the method is called linear interpolation. A power of 2.0 or higher suggests that the rate of change in values is higher near a known point and levels off away from it(*Johnston, et al., 2001; Isaaks, and Srivastava, 1989; Burrough, and, McDonnell,1998).*

## Materials and Methods

### Location and Extent of Studied Area

The republic of Iraq is located in the South - West of Asia, to the North - East of the Arab homeland, bounded on the North by Turkey, on the East by Iran, on the West by Syria, Jordan and Saudi Arabia, on the South by Arab Gulf, Kuwait and Suadi Arabia. Iraq lies between latitudes 29° 5´ and 37° 22´ north and between longitudes 38° 45´ and 48° 45´ east. The area of Iraq covers 435052 Sq. Km as shown below in Figure (1).

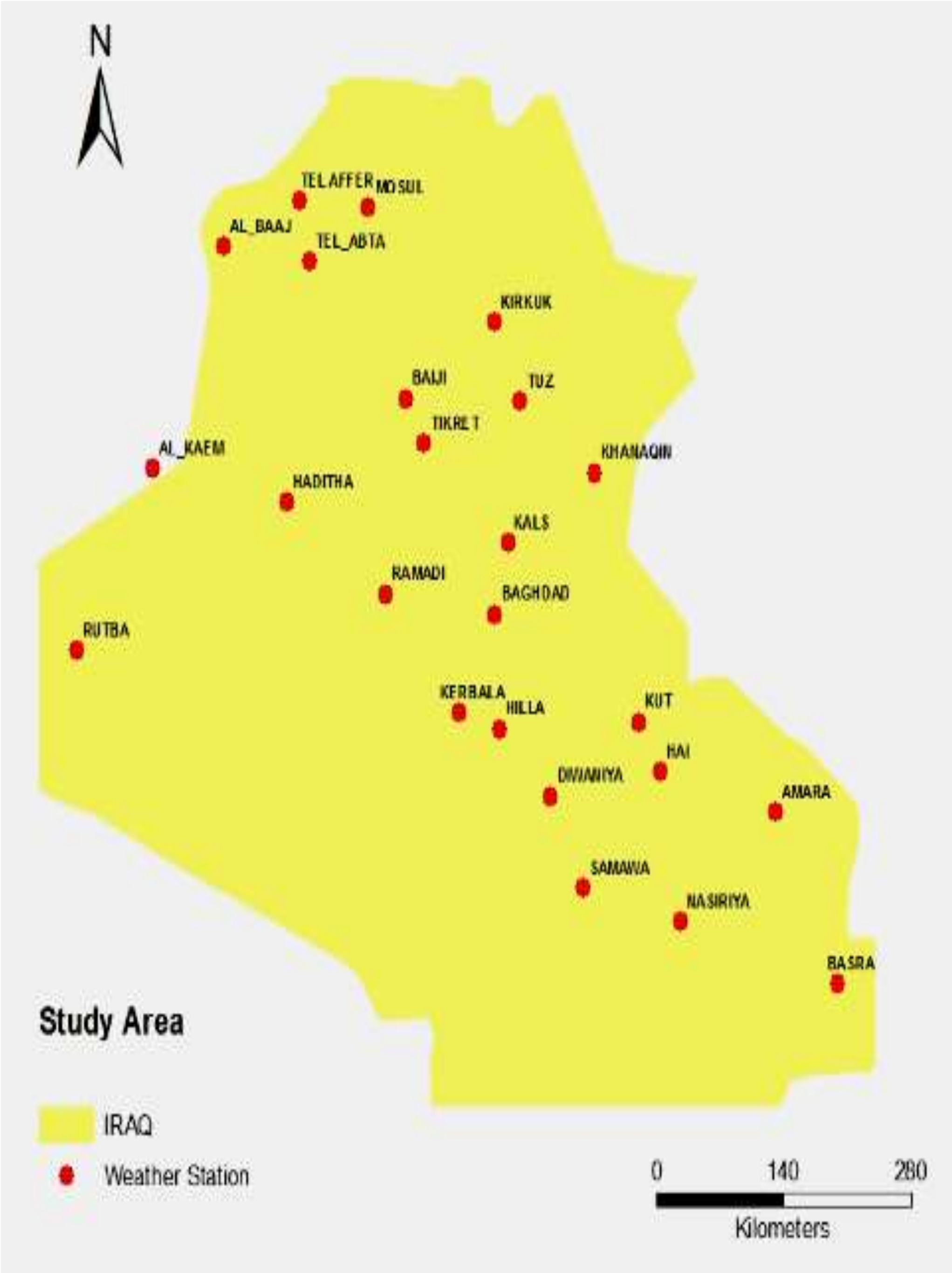



Figure (1) The Studied Area, Distribution of the Weather Stations

## Topography

Iraq is shaped like a basin, consisting of the Great Mesopotamian alluvial plain of the Tigris and the Euphrates rivers (Mesopotamia means, literally, the land between two rivers). This plain is surrounded by mountains in the north and the east, and by desert areas in the south and west, which account for over 40 percent of the land area. The Tigris and Euphrates rivers , flowing northwest to southeast before merging into the Shatt-Al-Arab and flowing into the Arabian Gulf. Other significant bodies of water nearby are the Mediterranean Sea, Black Sea, and Caspian Sea. Altitude ranges from lowest point at Arabian Gulf 0 m (mean sea level) up to highest point 3606 m. The Zagros Mountains extend up to 3000 meters in Iraq and form a natural border between the northeast region of Iraq and western Iran. The Taurus Mountains form the border between northern Iraq and southern Turkey(Yaseen, and, Monim, 2013).

## Climate

Iraq lies within the moderate northern region, system similar to that of Mediterranean where rainfall occurs almost in winter, autumn, spring and disappears in summer. The region is often divided into three rainfall zones according to the annual rainfall factor; Northern region, Middle region and Southern region(Shubbar 1999). Rainfall in Iraq varies from 50 mm per year in the SW to 1200 mm per year in the NE. The western desert of Iraq mostly receives <100 mm per year. The Mesopotamian flood plain and Jezira area receive 100-300 mm of precipitation per year. Rainfall in the foothills is 300-700 mm per year; the mountainous region of N and NE Iraq receives >700 mm of rain. Over half of Iraq lies within the arid and semi-arid zones (with<150 mm/year rainfall) (Hussein, *et al.*, 2007). The evaporation is very high in the country. The quantity of evaporation varies from one place to the other. Cyclones moving across Iraq are coming from the west; their source is the Atlantic Ocean. They are usually moving east toward the Mediterranean Sea and then in the direction of Cyprus, Lebanon and Jordan finally toward Iraq, or the Arabian Gulf or the Caspian Sea. The numbers of cyclones vary with seasons, months and places over which they are passing. Usually they are increasing in the winter, decreasing in the autumn and finally disappear completely in the summer. Also the number of cyclones moving over the south is greater than that moving across both zone of mountains and foothills. For instance, the annual number of cyclones in the south is about 75 while in the north is reaches 40. However, the north and northeast of Iraq usually receive higher amount of rain than the south. This is because the precipitations in the north are orthographic as much as it is cyclonic(Hassan and Mashkour, 1972).

## Meteorological Data

Historical records of monthly rainfall data for the time period 2003-2013 were acquired from the Iraqi Meteorological Organization and Seismology (IMOS). The long-term data were collected from 24 weather stations, which include; Khanqin, Kirkuk, Mosul, Teleafer, Tuz, Amara, Baghdad, Basrah, Hadithah, Hai ,Al_Baaj , Biji, Kahalis, Kut, Qaim, Ramadi, Samaraa, Tikrit, Diwaniya, Hella, Kerbela, Nasiriya, Rutba and Samawa), located at different regions of the country, The database was digitally encoded into a GIS database as shown in Figure (1).

## Result and Discussion

IDW is used the measured values surrounding the prediction location will have more influence on the predicted value than those farther away. Thus, IDW assumes that each measured point (weather station ) has a local influence that diminishes with distance. It weights the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted . The general formula is :

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i . Z(s_i) \quad (1)$$

Where $\hat{Z}(s_0)$ is the value we are trying to predict for location $s_0$, $N$ is the number of measured sample points surrounding the prediction location that will be used in the prediction with value equal 24, $\lambda_i$ are the weights assigned to each measured point that we are going to use .These weights will decrease with distance. $Z(s_i)$ Is the observed value at the location $s_i$. The formula to determine the weights is the following:

$$\lambda_i = d_{i0}^{-p} / \sum_{i=1}^{N} d_{i0}^{-p} \quad (2)$$

And

$$\sum_{i=1}^{N} \lambda_i = 1 \quad (3)$$

As the distance becomes larger, the weight is reduced by factor of $p$ .The quantity $d_{i=0}$ is the distance between the prediction location $s_0$ and each of the measured locations $s_i$.

Weights are proportional to the inverse distance raised to the power $p$. As a result ,as the distance increases the weights decrease rapidly .How fast the weights decrease is dependent on the value for $p$. If $p$=0 there is no decrease with distance and because each weight will be the same the prediction will be the mean of all measured values. As $p$ increases the weights for distant points decrease rapidly as can be seen in the Figure (2).If the $p$ values is very high only the immediate few surrounding points will influence the prediction .

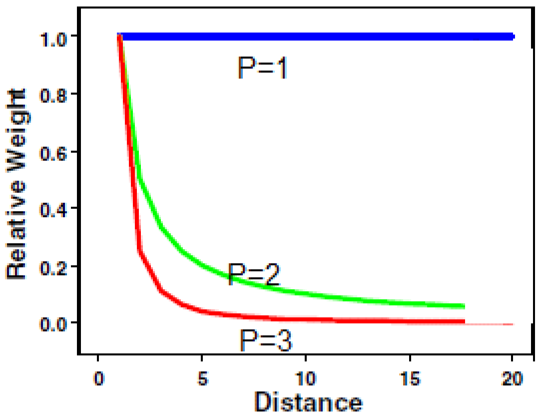



**Figure (2) Power Parameter**

IDW is an exact interpolator where the maximum and minimum values see Figure(3) in the interpolated surface can only occur at sample points. IDW assumes that the surface is being driven by the local variation which can be captured through the neighborhood.

We used value of *p* is equal to 2 to obtain the optimum estimation by minimizing root mean square prediction error RMSPE .The surface calculated using IDW depends on the selection of a power parameter (*p*) and the neighborhood search strategy.

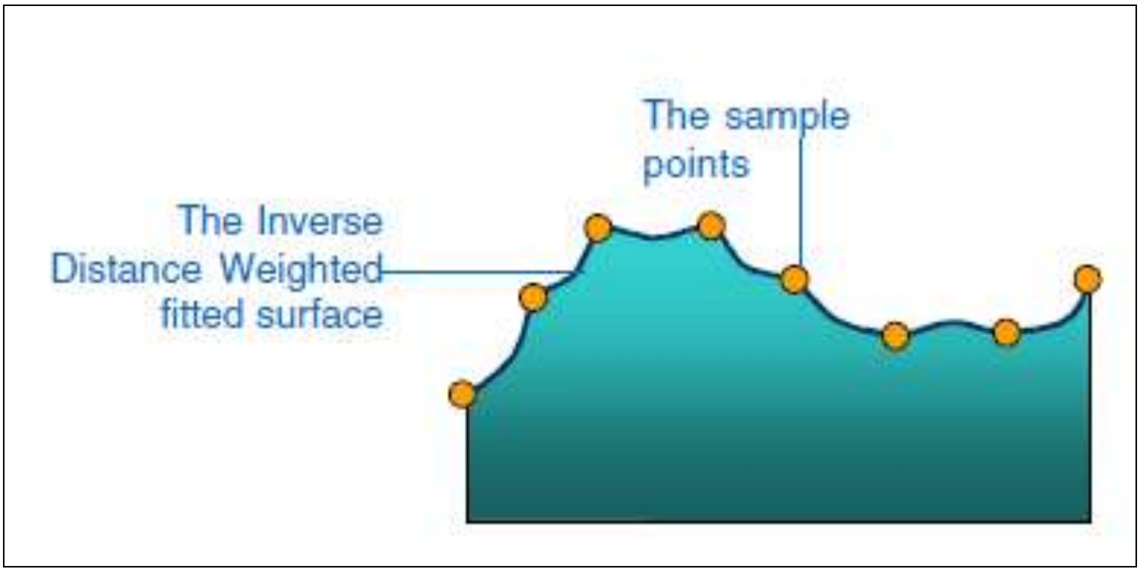
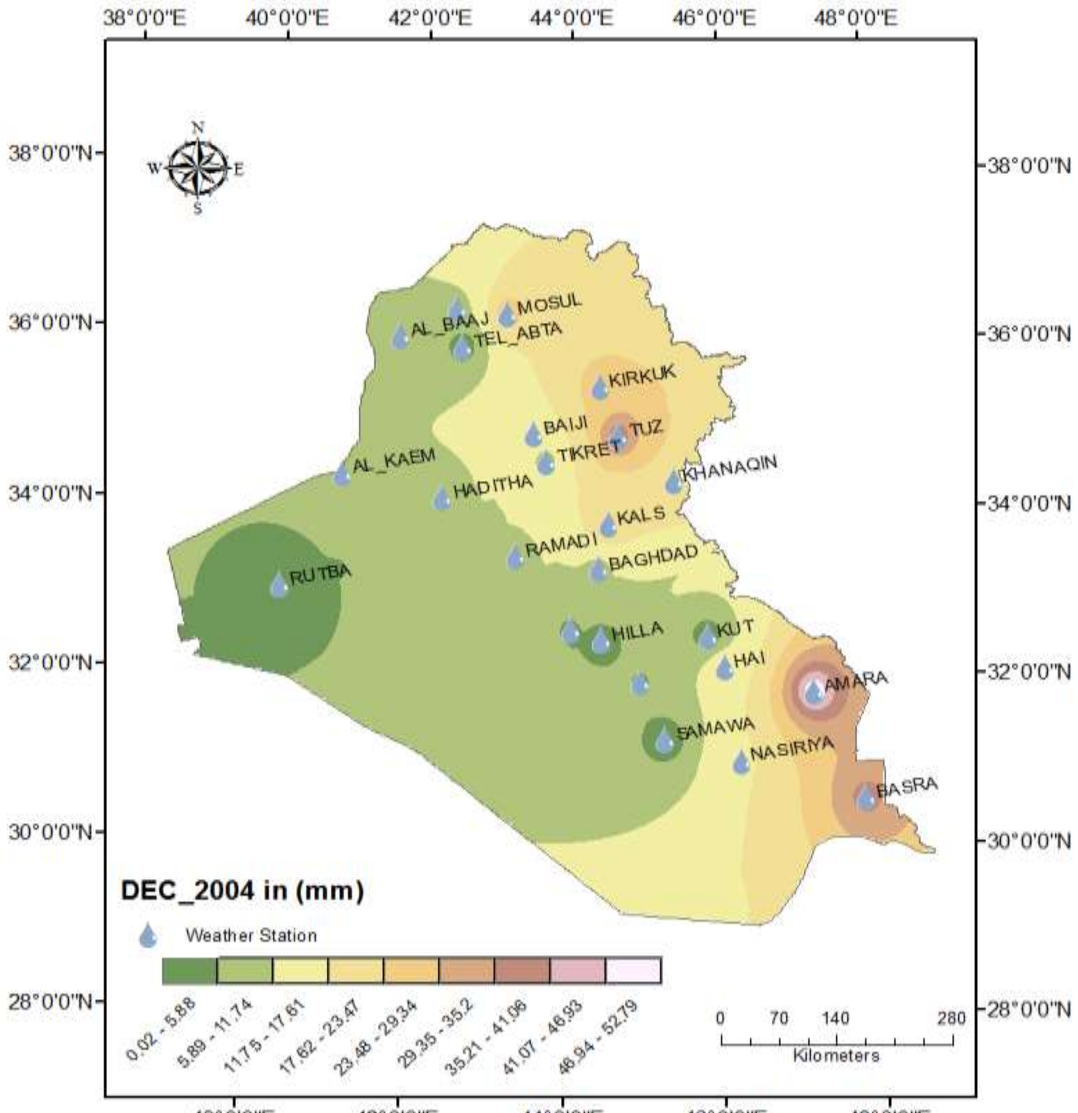
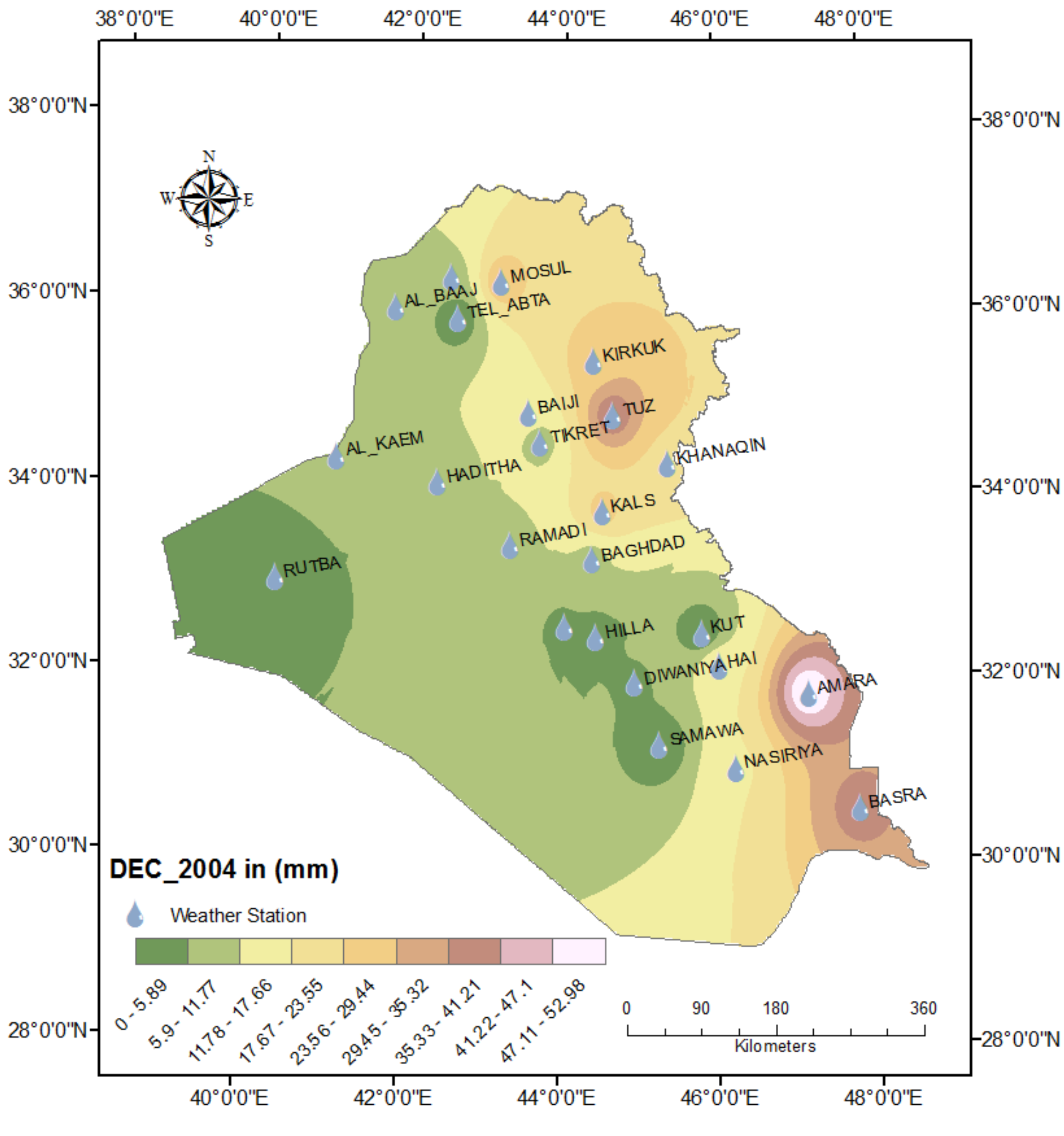



**Figure (3) IDW Concept**

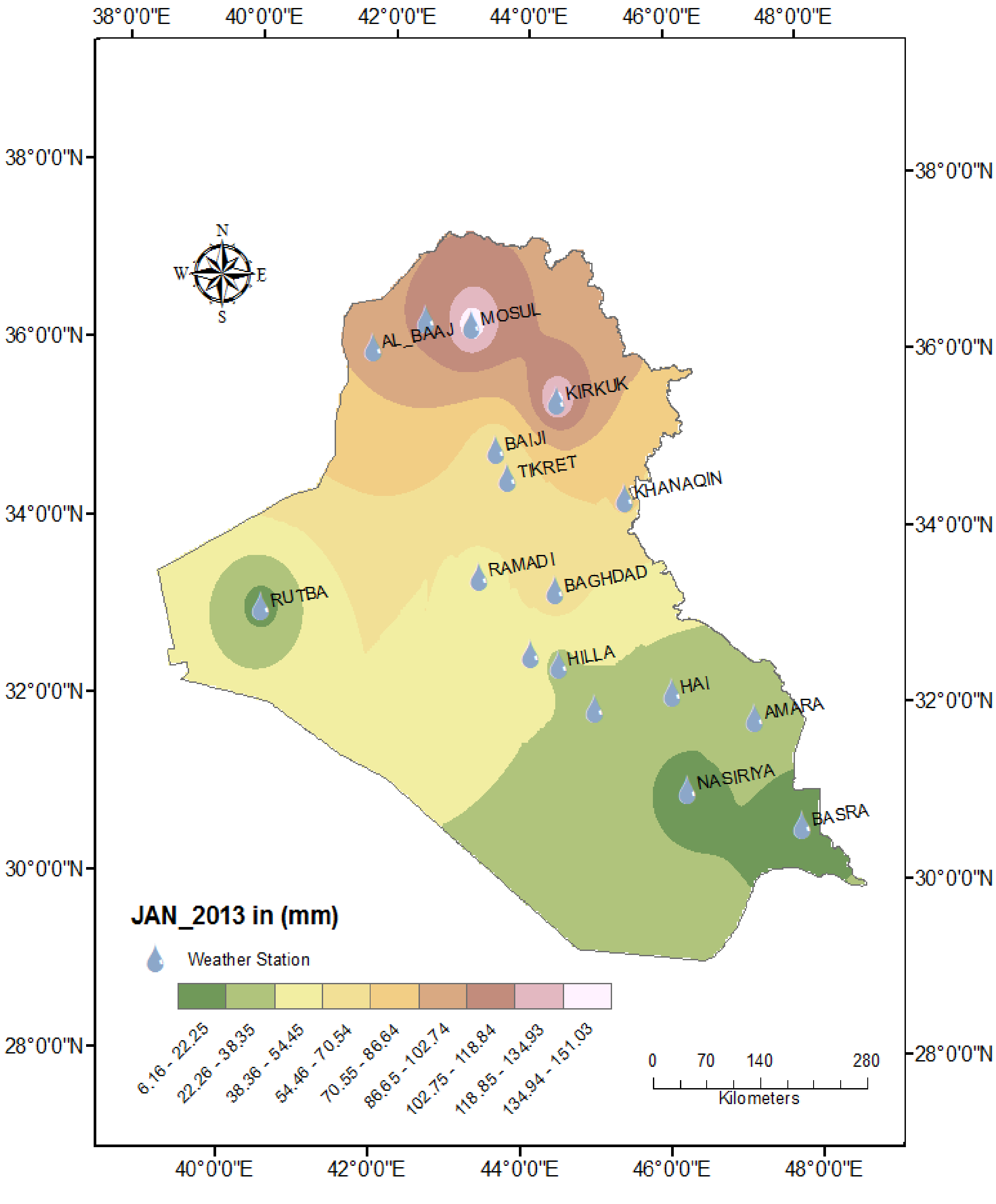
The following figures from figure(4) to figure(9) represent the rainfall maps in Iraq using the IDW method. The power factor used was p= 1.5 and p=2. Different months were chosen: January, October and December



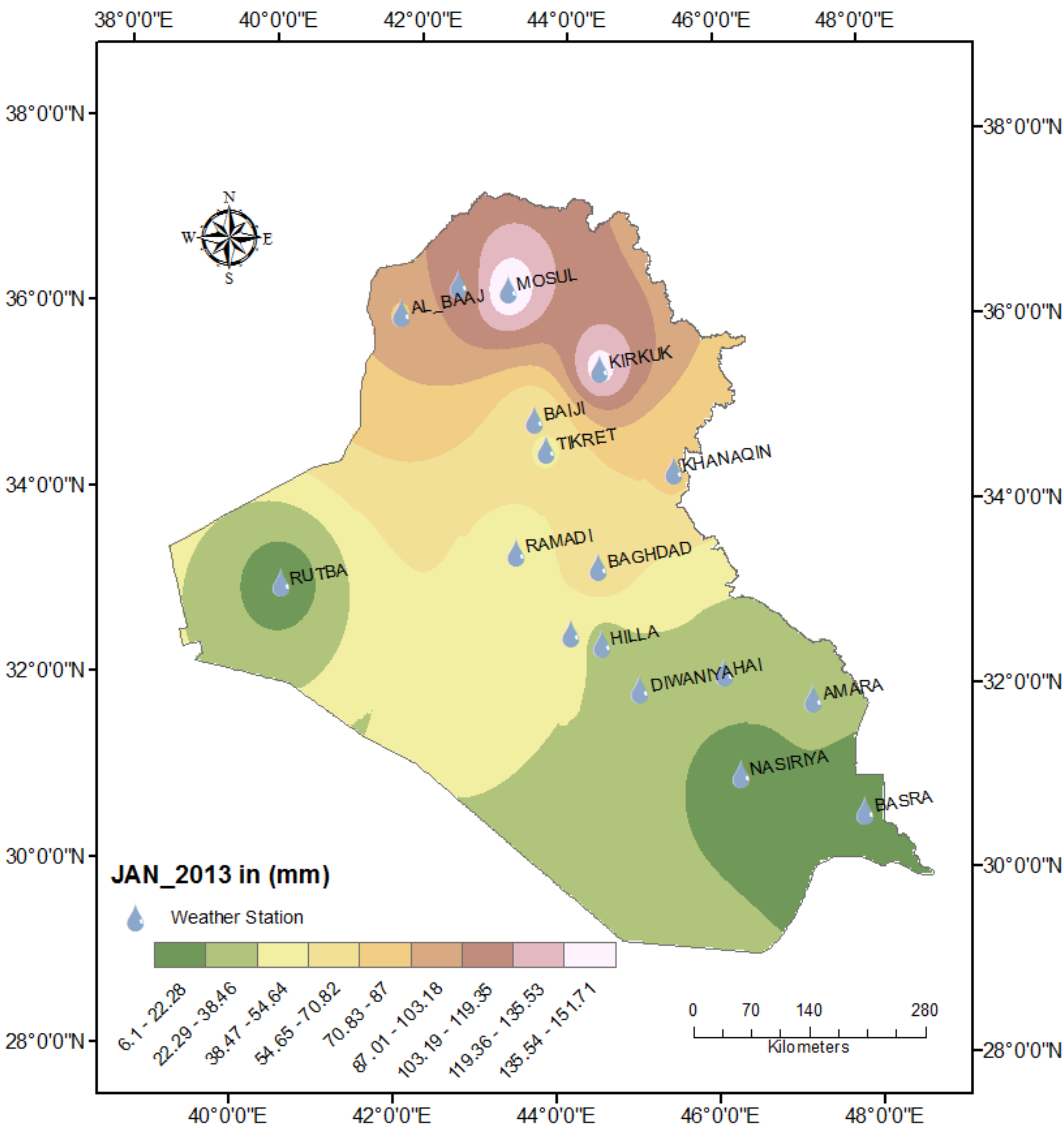

**Figure(4) Rainfall Surface for December 2004, P=1.5**



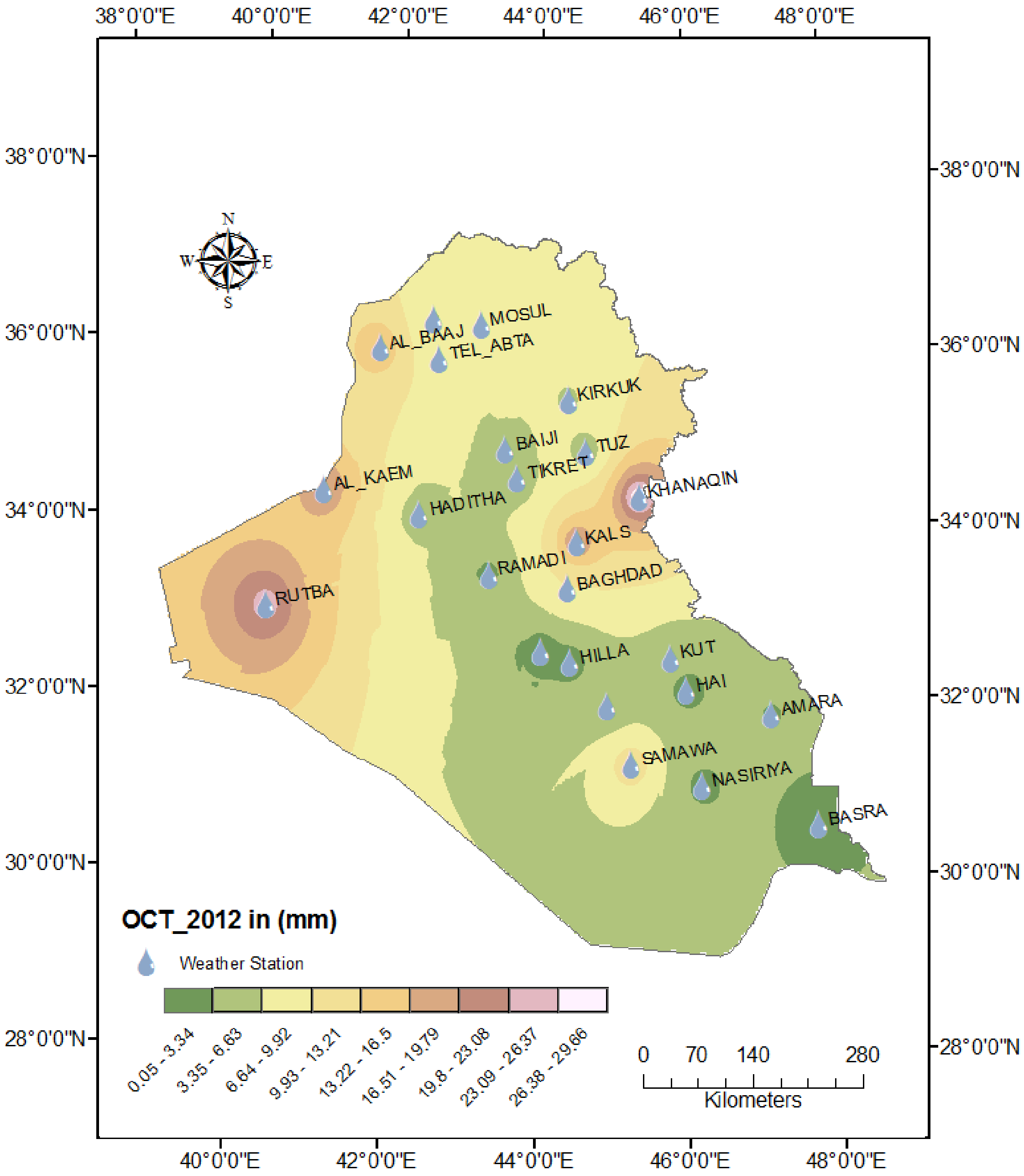

**Figure(5) Rainfall Surface for December 2004, P=2.**



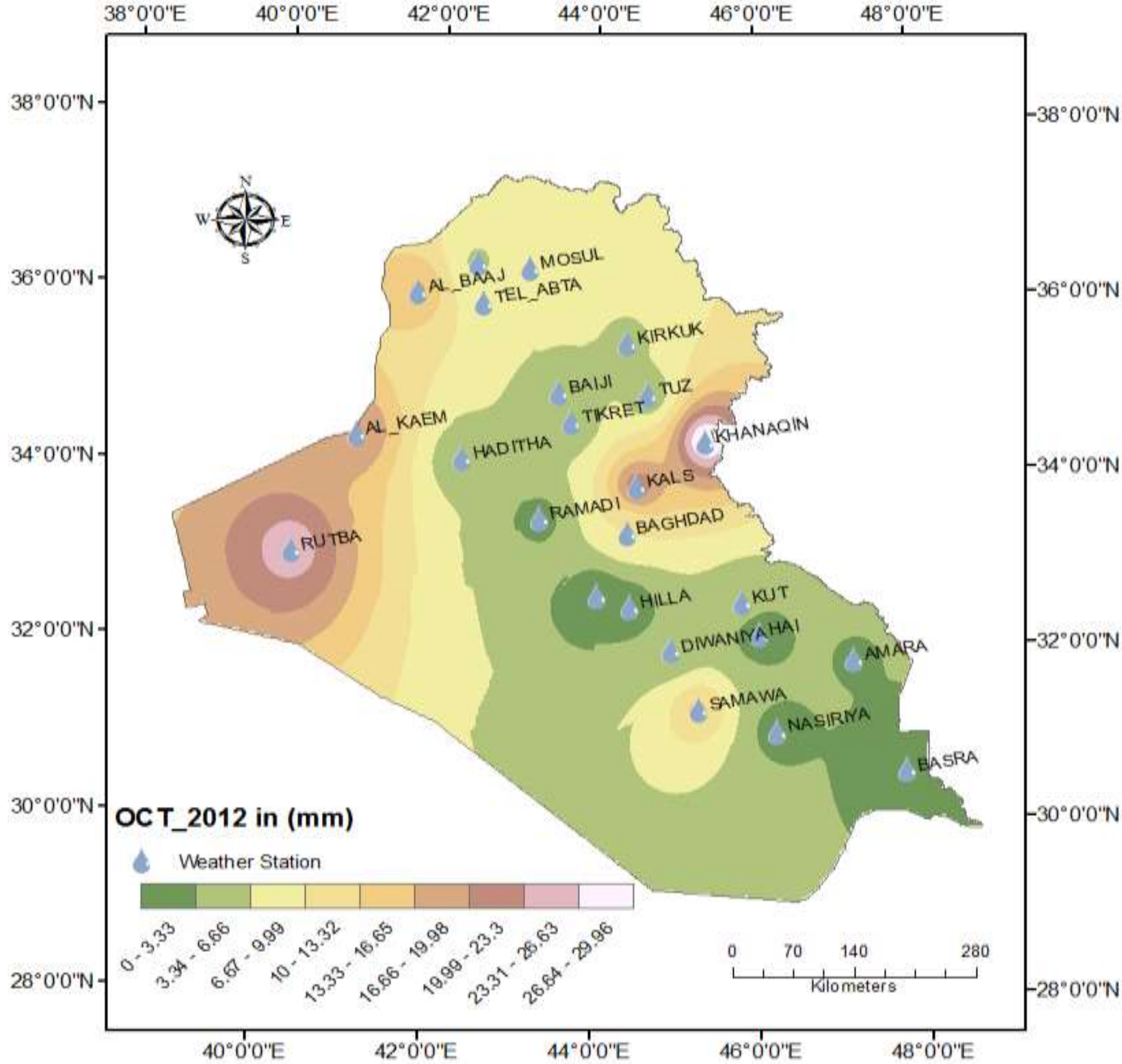

**Figure(6) Rainfall Surface for January 2013, P=1.5.**




**Figure(7) Rainfall Surface for January 2013, P=2.**




**Figure(8) Rainfall Surface for October 2012, P=1.5.**




**Figure(9) Rainfall Surface for October 2012, P=2**

The essence of spatial interpolation is to estimate the values of unobserved points based on known sample data. Due to non-availability of abundant measurement points, reliable estimation of temperature distribution poses a great challenge. Creation of digital grid maps makes it possible to obtain climatic information at any point, whether there is a weather station or not. Multiple factors condition the difficulty of map creation, such as the location of the site samples, spatial density, spatial variability etc. The annual temperature map developed can be useful for agricultural management in the region. Reliable calculation for agricultural management and improvement of climatic models at local scales can be obtained with increased efficiency.

## Conclusion

Rainfall in Iraq has been studied using IDW method in spatial analyst in GIS. Maps were produced for the last ten years because the continuous surfaces are important for agriculture , water resource management and environmental models. Inverse Distance Weighting (IDW) is a (quick) exact deterministic interpolator that requires very few decisions regarding model parameters, because it accounts for distance relationships only. This method assigns weights in an averaging function based on the inverse of the distance (raised to some power) to every data points located within a given search radius centered on the point of estimate.

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