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Predicted the Cumulative Annual Rainfall in Iraq using SDSM Modal

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ABSTRACT

Rain is deemed one of the most important climate elements. It must be given special attention for being the basis without which no kind of life in the world can be there. the aim of the study is to use Statistical models Downscaling (SDSM) where it is a universal model used to converting large scale output into a small scale that can be used to study impact at the local scale (Iraq)' to Forecasting cumulative annual rainfall for the next years where there are a few studies used this model in Iraq. Daily rainfall data from the Iraqi Meteorological Organization and Seismology (IMOS) (2007-2016) for the study areas (Baghdad, Karbala, Al-Hay, Mosul, Kirkuk, Khanaqin, Basra, Nasiriya, Diwaniya, and Rutba) is used to estimate the amount of rainfall by using SDSM. The model was used to estimate the rain values and then the results were compared with the actual values; the results were very close to each other. Also, the model used to predict the cumulative annual rainfall from (2017-2021), The result shows that the bigger amount of rainfall in the north region with (3821) mm and the lowest amount in the west region (665) mm, while middle region (1848) mm and south region (1828) mm.

KEYWORDS: SDSM, Rainfall, IMOS, ARIMA

الخلاصة

يعتبر المطر من أهم عناصر المناخ. يجب أن يولى اهتمامًا خاصًا لكونه الأساس الذي بدونه لا يمكن أن يوجد أي نوع من الحياة في العالم. الهدف من الدراسة هو استخدام نماذج إحصائية تصغير النطاق (SDSM) حيث أنه نموذج عالمي يستخدم لتحويل المخرجات الكبيرة الحجم إلى مقياس صغير يمكن استخدامه لدراسة التأثير على النطاق المحلي (العراق)' التوقع هطول الأمطار السنوي التراكمي لـ السنوات القادمة حيث توجد دراسات قليلة استخدمت هذا النموذج في العراق. تستخدم بيانات هطول الأمطار اليومية من هيئة الأرصاد الجوية العراقية وعلم الزلازل **(IMOS)** (2016-2007) لمناطق الدراسة (بغداد ، كربلاء ، الحي ، الموصل ، كركوك ، خانقين ، البصرة ، الناصرية ، الديوانية ، الرطبة) لتقدير كمية الهطول باستخدام SDSM. تم استخدام النموذج لتقدير قيم المطر ومن ثم مقارنة النتائج مع القيم الفعلية وكانت النتائج متقاربة جدا. كما تم استخدام النموذج لتنبؤ هطول الأمطار السنوي التراكمي من (2021-2017) ، وأظهرت النتيجة أن أكبر كمية لهطول الأمطار في المنطقة الشمالية (3821) ملم وأقل كمية في المنطقة الغربية (665) ملم ، بينما الوسط. المنطقة (1848) ملم والمنطقة الجنوبية (1828) ملم.

INTRODUCTION

Rain is deemed one of the most important climate elements. It must be given special attention for being the basis without which no kind of life in the world can be there.

Some study showed strong rainfall spatial variability, with the largest value being found in the headwater of the river [1]. The low amount of rainfall the season will be drought but if large amount may be floods happened, both of them have an effect on the human health [2] where Precipitation data finds wide application in public health research. Precipitation occurrence has frequently been associated with waterborne diseases, insect population outbreaks, and disease transmission modes [3]. Along with a possible climate change-induced increase of rainfall intensities, is one of the key factors accountable for (increased) flooding in urban areas. Consequently, higher runoffs have an impact on sewer system performance in terms of higher risk of flooding and decrease of storm water treatment performance [4].

Aircraft also affected by rainfall, for example, can decrease visibility at least in the following two ways. In one way through the scattering of light from a large number of liquid droplets, high rainfall rates can reduce the visibility to less than 400 m. In the other way through the water film and splashing of raindrops on the windshield of an aircraft, high-speed windshield wipers will possibly deteriorate or even lose their effectiveness when encountering a heavy rain. Rain also influence the accuracy of radar scatter meter measurements [5]. Rain estimate and prediction have been one of the most scientifically and technologically challenging problems around the world in the last century. It's an effect on many human activities [6].

The importance of rain and its impact on the climate many studies have predicted and estimated the values of rainfall. Asraa Khtan etal (2008) estimated the maximum possible rainfall in selected stations of Iraq using two models (meteorology and statistical) where it was found that the values of the meteorology model to predict the maximum rainfall within 24 hours gave higher accuracy than the statistical model because of the different rainfall nature of the study area [7]. while Hassanein Khalil Abdullah (2008) studied the analysis of precipitation data in Iraq using Markov chains. The rain was described in three cases: rain year, average year precipitation, dry year. It was found that the future data for Sulaymaniyah, Samawah, Nasiriyah stations will not depart from the characteristics during the period of time studied, over a long time, the Sulaymaniyah station will have the potential to show a rainy or medium rain or dry season, whereas in the Samawah station, the probability of a rainy or dry year is high. While the probability of an average year of precipitation is weak, In the Nasiriyah station, in the long term, the probability of an average year of precipitation is greater than that of a rainy year or a dry year [8]. Amr H. El-Shafie et al. (2011) An analysis of two statistical models developed for rainfall forecast on a yearly and monthly basis in Alexandria, Egypt shows that an artificial neural network (ANN) has a better performance than a Multiple Linear Regression (MLR) model. The MLR model revealed a humble prediction performance. The linear nature of MLR model estimators makes it inadequate to provide good prognostics for a variable characterized by a highly nonlinear physics[9]. Zulkarnain Hassan etal (2012) used statistical downscaling model for long lead rainfall prediction in Kurau River catchment of Malaysia, prove that the SDSM model has the ability to perform well during calibration and validation. The study results show that the Kurau River basin will become wetter in the future. The results of downscaling of daily rainfall for future emission show an increment trend for each month, except for March, September, and December. The increment of annual rainfall has also been observed in this study [10].

Chandhina and Kansal (2016) used Statistical Downscaling Model (SDSM) to downscale the daily rainfall in Piperita watershed of Chhattisgarh state. They used daily rainfall data for the durations 1961 to 1990 and 1991 to 2001 to calibrate and validate the model respectively with large-scale National Centers for Environmental Prediction (NCEP) reanalysis data. Monthly rainfall has been estimated using predicted daily rainfall for duration of 2011 to 2040, 2041 to 2070 and 2081 to 2100 under consideration of GCM Hadley Centre Coupled Model, version 3 (HadCM3) outputs for A2 and B2 scenarios. They found SDSM as a good tool in terms of its efficiency to predict rainfall at monthly scale under A2 & B2 emission scenarios of HadCM3 model[11] . Mustafa Al-Mukhtar *et al.* (2019) proved a satisfactory performance of SDSM for simulation of maximum-minimum temperatures and precipitation for future periods. All considered stations and the scenarios were consistent in predicting increasing trend of maximum-minimum temperature and decreasing trend of precipitations[12].Abbas etal (2020) An evaluation of the anticipated future changes in the characteristics of precipitation for Mosul city was done considering 20 ensembles of GCM output of HadCM3 The Special Report on Emissions Scenarios (SRES) B2a emission scenario with the applied of statistical downscaling (SDSM) modeling approach. The downscaling of rainfall data scenario refers a future increasing during the next 20 years period. Analysis of data provides a convenient agreement between observed and downscaled data [13].

Statistical Methods

Many types of Statistical methods use to estimate and predicted for example: Time series, Markov property, and autoregressive integrated moving average (ARIMA) model, gamble, curve fitting, downscaling. * In this study used curve fitting and downscale [14].

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Downscaling

The process of converting large scale GCM output into a small scale that can be used to study impacts at local scale. There are two main approaches of downscaling viz., dynamical and statistical. Statistical methods for estimating rainfall are considered the fastest method but they often give values close to real values.

1- Statistical Downscale

Statistical downscaling derives a statistical or empirical relationship between the variables simulated, called predictors, and station-scale hydrologic variables, called predictands. It is seen that accurate estimates of the local variables are strongly dependent on the quality and the length of the data series used for the calibration and on the performance of the models in capturing the variability of the observed data. Two-step processes. The first is to develop the statistical relationship between local climate variables (predictand) and large-scale atmospheric variables (predictor variables) and next is to apply the established relationship to the output of GCM to simulate future climatic data [15].

Statistical downscaling is based on the following assumptions:(i) suitable relationships can be developed between the large-scale predictors and local predictands; (ii) the relationships are valid under future climate conditions; and (iii) the predictor variables and their changes are well simulated by GCMs.

2- Dynamic Downscale

Dynamical downscaling involves nesting a regional climate model (RCM) into a GCM. A specific location is defined and high-resolution model basically regional climate model (RCM) driven by boundary conditions from a GCM is used to derive finer- spatial scale information. They operate currently at scales of 20–50 km, instead of using mathematical equations, dynamical downscaling uses numerical meteorological modeling to bring global-scale projection down to the regional scale. The merit of using RCM is that they can resolve smaller-scale atmospheric features better than the host GCM, is its potential for capturing mesoscale non-linear effects and providing information for many climate variables, whereas the demerit is that they demand considerable computing resources and are expensive as GCMs. Due to the computational cost of RCM simulations, these are usually restricted to time slices. The lack of information provision is at the point or station scale. RCM model skill is dependent on biases present in the driving GCM and regional forcing such as orography, land-sea contrast, and vegetation cover. Since boundary conditions are derived from a specific GCM, the use of different GCMs will result in different projections [16]

METHODOLOGY

Iraq is divided into three regions: northern region (Mosul, Kirkuk, and Khanaqin), middle region is (Baghdad, Karbala, and Al-Hay), southern region (Basra, Nasiriya, and Diwaniya) and the western region (Al- Rutba) as shown in Figure 1.

Figure 1. Study Areas [13].

The data used are represented by the values of the daily rainfall (mm) for the period (2007-2016) which is taken from the Iraqi Meteorological Organization and Seismology. The data of the climatic elements (atmospheric variable), that effect on rainfall are taken from the Canadian website (http://www.cccsn.ec.gc.ca/?page=pred-hadcm3.) in the format of GCM for the period (2007-2020) for the study area as shown in Table (1).

Table 1. Climatic elements

Atmospheric pressure level	Code	GCM Variables Descriptions
1013.25 hPa	mslp	Mean sea level pressure
1000 hPa	p_f	Surface airflow strength
	p_u	Surface zonal velocity
	p_v	Surface meridional velocity
	p_z	Surface vorticity
	p_th	Surface wind direction
	p_zh	Surface divergence

850 hPa	p8_f	850 hPa airflow strength
	p8_u	850 hPa zonal velocity
	p8_v	850 hPa meridional velocity
	p8_z	850 hPa vorticity
	p8th	850 hPa wind direction
	p8zh	850 hPa divergence
	p850	850 hPa geopotential height
	r850	850 hPa relative humidity
500 hPa	p5_f	500 hPa airflow strength
	p5_u	500 hPa zonal velocity
	p5_v	500 hPa meridional velocity
	p5_z	500 hPa vorticity
	p5th	500 hPa wind direction
	p5zh	500 hPa divergence
	p500	500 hPa geopotential height
	r500	500 hPa relative humidity
Near surface	Shum	Surface-specific humidity
	temp	Mean temperature at 2 m height
	rhum	Surface relative humidity

Estimate of annual rainfall values

The program of SDSM version 4.2 has been used to estimate the cumulative annual rainfall values. To apply this program in Baghdad station, to estimate the cumulative annual rainfall to the period 2007-2011 as shown in Figure (2), it should be taken some steps in preparing:

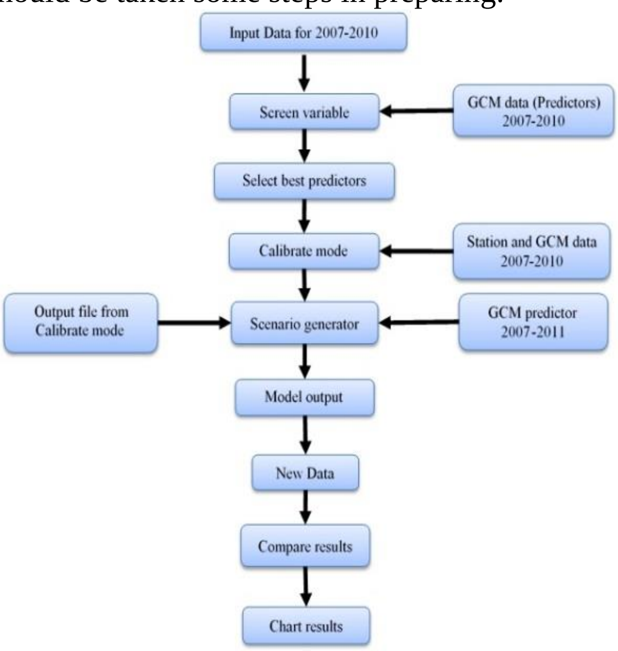

Figure 2. The diagram of SDSM process.

The transform data in the model was tested for actual rainfall data taken from IMOS, did not give good results when compared with the actual values. Therefore, the calculated data from the selected model have used the method (curve fitting) in this study, where gave good results better than calculated data from the model SDSM. Addition, in this program we have selected predictand file option which is in data or text format. Then we have entered the rain data file for a previous period (data known for 4 years or more).

The relationships between rain and atmospheric variable are determined by screen variables. After installing all the settings model and find out what the most elements have an effect or relation to the data entered rain comes the stage of calibration data, we specify the model type annual, where it was chosen annually on the basis of the rainfall data obtained. Next perform the process by pressing Calibrate.

Scenario Generator: is the final step of the model which is estimated the amount of rainfall or forecasting for the coming years by selecting the calibration file in the select parameter file. Specify the path of the GCM data in the GCM directory for the coming years (2007-2011) which used with calibration to estimate amounts of rain. As well as specifying the name and path of the estimating file produced in the (select output file). By pressing the Generate button, you will produce an OUT file.

RESULTS AND DISCUSSION

The estimated rainfall data for the next years as and comparison was made between the actual cumulative annual rainfall values with the estimated for Baghdad in the program and found that they are close to a good rate, as the highest approximation record in the period (2007-2011), the highest record difference in the year (2007-2013) because the year 2013 experienced the highest rain during 24 hours by 79 mm within one day as shown in Figure (3), which shows the real and calculated values of the city of Baghdad for the study period.

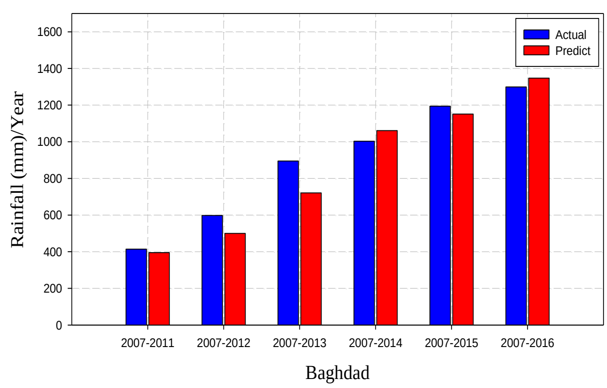

Figure 3. The actual and predict cumulative annual rainfall for Baghdad station.

The actual values calculated with all stations and for all periods of the study were compared and found to be very close to each other as shown in Table (2).

Table 2. The actual and estimated cumulative annual rainfall for northern region.

Years	Mosul		Kirkuk		Khanaqin	
	Rainfall (mm)		Rainfall (mm)		Rainfall (mm)	
	Actual	Estimate	Actual	Estimate	Actual	Estimate
2007-2011	1169	1103	1022	1005	993	1015
2007-2012	1447	1292	1314	1240	1295	1180
2007-2013	1903	1706	1709	1891	1651	1511
2007-2014	2244	2212	2028	2000	1907	1917
2007-2015	2536	2528	2343	2299	2298	2147
2007-2016	2826	2829	2664	2627	2498	2575

Table 3. The actual and estimated cumulative annual rainfall for southern region.

Years	Diwaniya		Nasiriya		Basra	
	Rainfall (mm)		Rainfall (mm)		Rainfall (mm)	
	Actual	Estimate	Actual	Estimate	Actual	Estimate
2007-2011	185	150	377	399	237	252
2007-2012	284	231	493	458	343	355
2007-2013	408	323	668	612	458	498
2007-2014	514	436	887	741	574	608
2007-2015	653	534	981	992	675	711
2007-2016	722	672	1039	1082	780	816

Table 4. The actual and estimated cumulative annual rainfall for middle region.

Years	Baghdad		Karbala		Hay	
	Rainfall (mm)		Rainfall (mm)		Rainfall (mm)	
	Actual	Estimate	Actual	Estimate	Actual	Estimate
2007-2011	414	395	329	295	438	401
2007-2012	598	500	408	409	519	539
2007-2013	895	721	594	489	707	615
2007-2014	1003	1061	700	694	896	814
2007-2015	1194	1151	819	803	1090	1006
2007-2016	1299	1347	996	924	1214	1205

Table (5): The actual and estimated cumulative annual rainfall for western region.

Years	Rutba	
	Rainfall (mm)	
	Actual	Estimate
2007-2011	351	339
2007-2012	424	534
2007-2013	559	642
2007-2014	717	796

Predict of cumulative annual rainfall values

The program was also used to predict the cumulative annual rainfall values for (2017-2021) from (2007-2016) for all study regions.

In the middle region, Figure (4) shows that the cumulative annual rainfall will increase in Baghdad more than the other stations at an annual mean of (138.4) mm where in Karbala, the cumulative annual mean rainfall will be (104.8) mm.

For the southern region as shown in Figure (5), the cumulative annual rainfall in Nasiriyah is more than Diwaniyah, where the cumulative annual rainfall mean (102.4, 110.4, and 151) for the stations (Diwaniyah, Nasiriyah, and Basra) respectively. In Northern region as shown in Figure (6), expected for the next five years to increase the cumulative annual rainfall in Mosul with larger amounts than Kirkuk and the Khanaqin at an annual mean (268) mm. The mean of increase in the cumulative annual rainfall for the western region is expected to be greater than the calculated mean for the study period, as expected (133), as shown in Figure (7).

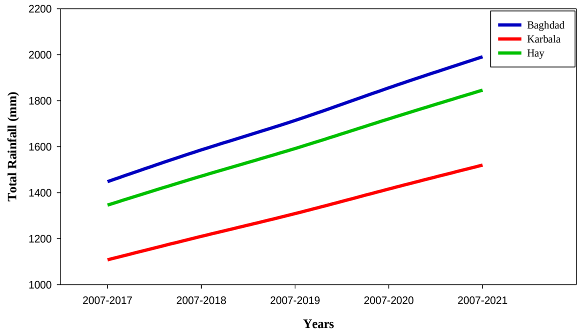

Figure 4. The general trend of predicted value for middle region.

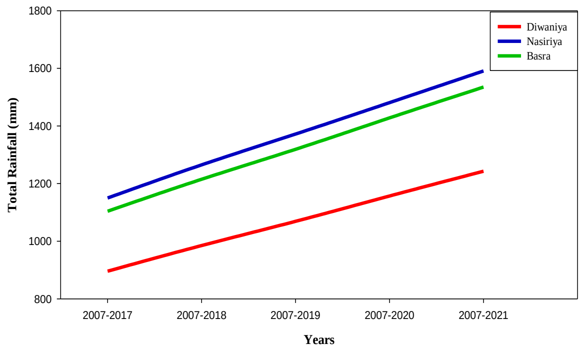

Figure 5. The general trend of predicted value for southern region.

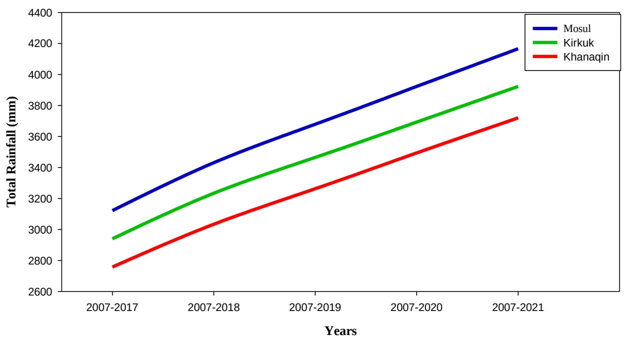

Figure 6. The general trend of predicted value for northern region.

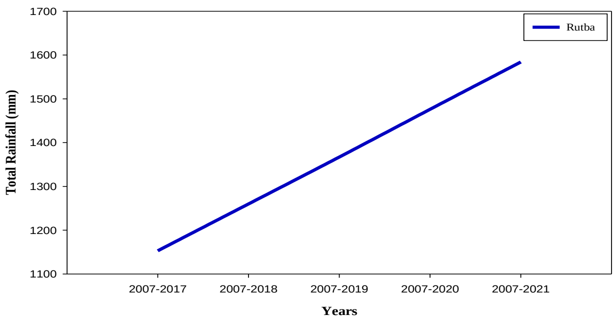

Figure 7. The general trend of predicted value for western region.

From the map in Figure (8), notice that the northern region has the highest cumulative annual rainfall in the next five years, while the southern and central regions are almost converging, the western is the smallest.

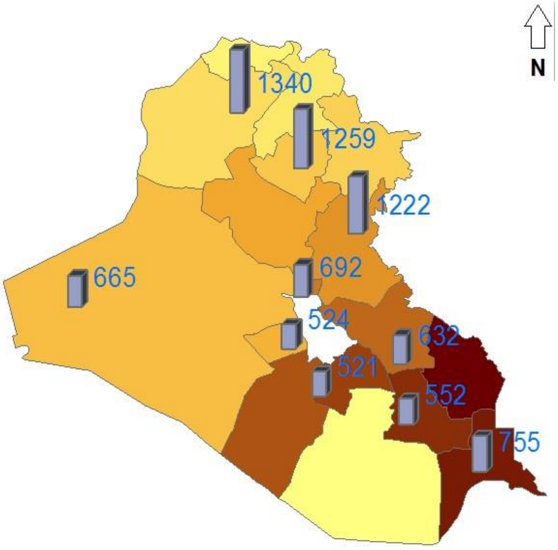

Figure 8. The predicted cumulative annual rainfall for (2017-2021).

CONCLUSIONS

Through the statistical analysis of rainfall data for the study period and for all selected areas, it is found that:

1-All study areas show an increase in the trend of rain and varying degrees where the northern and central regions have a high increase either the southern increase slightly and western increase significantly.

2-The model of downscaling can be used to predict a cumulative annual rainfall for next year with good results.

3-From predicting values of cumulative annual rainfall for the next five years, the northern region will bring the highest amounts (3821) mm of rainfall and the western region lesser amounts (665) mm.

4-The model of downscaling gave very good results in estimating the amounts of accumulated annual which makes it a good way to estimate the amount of rainfall in the absence of data for a certain period.

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