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MODELING FUTURE RAINFALL DATA AT SHAHAT METEOROLOGICAL STATION AND MONITORING ITS CHANGE FOR THE PERIOD (1961-2099) USING SDSM

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ABSTRACT

This research aims to predict future rainfall rates for the period (2010-2099). Depending on the daily rainfall rates of the Shahat Meteorological Station for the base period (1961-1990) using the ((Statistical Downscaling Model (SDSM)) technique, based on climate change scenarios (A2a) (B2a); these are scenarios approved by the IPCC Climate Change Team in a report It was known as SRES in the year 2000 to develop climate and environment forecasts based on greenhouse gases, to detect the direction and amount of change in rainfall rates for future periods, namely: (2010-2039), (2040-2069), (2070-2099), compared to the base period. (1961 - 1990). The results showed trends towards a decrease in rainfall rates at Shahat Station, compared to the base period with future periods, especially in the period (2010-2039), and also showed that there is a change in the amounts of rainfall at the seasonal level.

1.0 Introduction

Modelling is defined as part of the simulation of reality. Simulations have been developed mainly to obtain answers related to experiments that cannot or are difficult to perform. An example of this lies in the difficulty of finding accurate solutions when thinking about some scientific problems and issues that we want to find. Solve it. The model is defined as a formal framework for representing the basic features of a complex system with a few key relationships. This model takes different forms, such as (forms, mathematical equations, or computer programs) [1].

Today, global climate change has become inevitable and Inevitable, and will lead to changes in the entire universe, and the occurrence of more impactful natural disasters. This requires us to change our lifestyle, production, and consumption, especially since controlling the size of these changes is still within our reach.

Climate modelling is based on global climate models referred to as the General Circulation Mode (GCM) models. Global climate system to increase Greenhouse gas concentrations, which will be used to project future climate elements such as rainfall [2].

Global climate models use Regional Climate Models (RCM) as inputs in analysing and determining the strength of relationships between the different climate elements. The models cannot provide direct information for smaller scales than their resolution capacity. Therefore, a process known as shrinking pronunciation appeared by adapting the properties of large-scale models. Applied to smaller regions, the method can be dynamic, statistical, or a combination of the two. The dynamic method requires housing high-resolution models for limited regions within a less detailed global model [3]

The importance of this study comes in the application of these models to develop future projections of rainfall at the Shahat meteorological station until the year 2099, to know the extent of the impact of climate change on its seasonal and annual rates, to present its results to agricultural and economic policymakers in the Libyan state to take the necessary measures and measures.

2.0 Importance of the Study

- The importance of the study lies in highlighting one of the statistical techniques that is concerned with the future prediction of climatic elements.
- Evaluating the amount of change in rainfall rates at the Shahat meteorological station during the twenty-first century, according to the proposed scenarios.
- Supporting studies on the future of the climate in Libya, especially concerning the rain component.

3.0 Objectives of the Study

- Applying the statistical scaling model (SDSM) to derive a series of local rainfall data for Shahat Meteorological Station.
- Identifying the future trend and behaviour of rainfall in Shahat (monthly, quarterly, and annual), based on simulations of the most important global models for future climate prediction and its scenarios during the period 2010-2099.

4.0 Problems

- Can we predict the amounts of rainfall in Shahat by SDSM until 2099? How true are these predictions?
- Is there a change in the annual and monthly rainfall rates in Shahat in the future periods compared to the base period? And for which scenario is the rates followed?

- Is there a change in the trends of seasonal rainfall rates in Shahat in the future periods compared to the base period? And for which scenario do they follow in their rates?

5.0 Hypotheses

- **H 1:** The SDSM technique has proven its ability to predict the amounts of rainfall at the Shahat meteorological station, as well as its accuracy when calibrating the modeled data with the data recorded at the National Center of Meteorology in Tripoli.
- **H 2:** There is a clear change indicating a decrease in the monthly and annual rainfall rates at Shahat station, according to the two scenarios (A2a, B2a).
- **H 3:** The rainfall rates at Shahat station tend to change at the seasonal level during the future periods (2010-2099) compared to the base period according to the two scenarios (B2a) and A2a.).

6.0 Limits

The Shahat Meteorological Station is located in northeastern Libya Figure 1, at latitude 32.8034486 degrees north and longitude 21.8628205. It is located at an altitude of 621 meters, and it is a synoptic station bearing the international number 62056 [4].

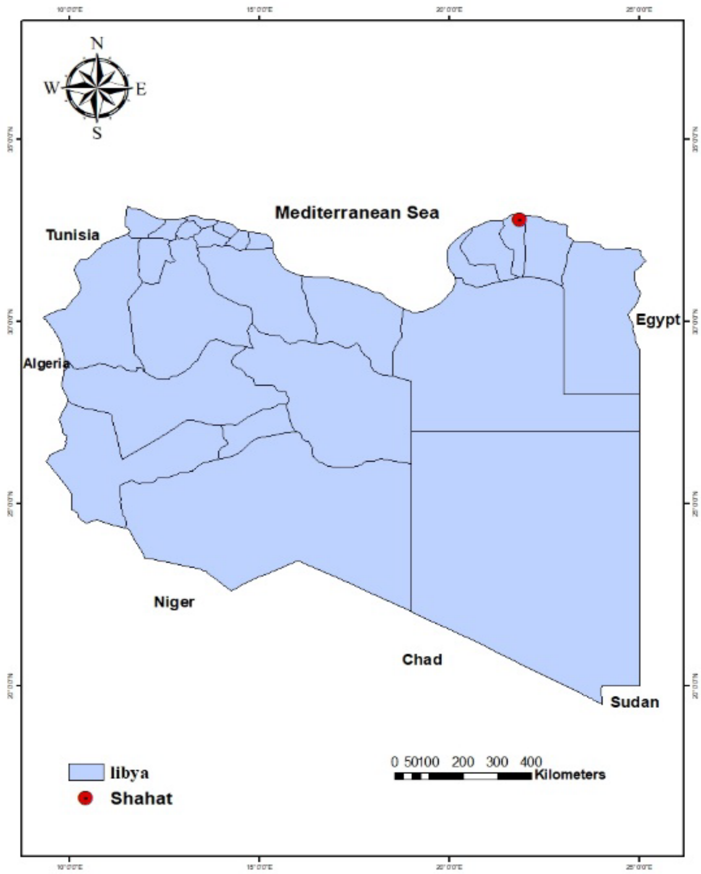

Figure 1: Shahat Meteorological Station.

Source: Researchers using GIS based on (The National Atlas, 1978, p25)

7.0 Materials and Methods

This study relied on the statistical analytical approach of the daily averages of rainfall rates for the Shahat station issued by the Libyan National Meteorological Center for the period (1990-1961), to be used in simulations or future modeling for the period 2010-2099 AD, using the technique (Statistical Downscaling Model (SDSM)) It is a tool used to support decision-making in predicting future climate elements such as rainfall, based on scenarios of greenhouse gas emissions, to understand climate change over time during the twenty-first century, which is represented by the (HadCM3) model issued by the Hadley Center of the Meteorological Office. In the United Kingdom, and aspects of its performance in climate simulation are run by the Intergovernmental Panel on Climate Change [5], which is one of the most important scenarios in the study of climate change. This scenario is mainly based on stabilizing greenhouse gas emissions rates that It was recorded in the year 2000, as the climate system, according to this scenario, is subject to a degree of change based on the current concentrations of the various elements of the atmosphere. In the field of climate, scenarios are used due to the uncertainty of change at the regional level [6]. The HadCM3 scenarios are:

- **Scenario A2a:** which describes a very diverse, heterogeneous, self-reliant world, whereby economic development is regionally oriented and varies among regions. It assumes that there is a variation in fertility patterns across regions, which means a continuous growth in the world population and an increase in population density.
- **Scenario B2a:** This scenario is directed towards global solutions for economic, social and environmental sustainability. It depends on alternative energy developments, achieving social and economic justice, and a reduction in the intensity of resource exploitation. It also assumes that there will be a continuous increase in the population, but at a slower pace than scenario A2a, and at an average rate of economic development. And with less rapid and more diversified technical change [7].

8.0 The first topic rainfall forecasting by SDSM.

The Statistical Downscaling Model (SDSM) is one of the techniques adopted by the International Panel on Climate Change (IPCC), as it is used to deal with data of various climatic elements to assess the effects of regional climate change and support decision-making related to future prediction of the state of climate and climate changes and what it will be, as well as to evaluate local statistics and its effects on climate change. Through this program, scenarios are used to help determine whether variables. The stages of SDSM modeling are as follows:

8.1 Data Quality Control

Quality control phase The daily data of rainfall rates at Rasa Shahat station were checked and ensured that they match the numerical values for the base period (1961-1990) representing 10957 days, checking for missing and incomplete values and processing them as well as visual monitoring of the highest value and lowest value of rainfall to adjust if any flaw.

8.2 Screen variables

In the second stage, the strength of forecast or prediction variables such as altitude at sea level, atmospheric pressure values, and other 26 variables from the GCM model (Table 1) are examined, along with the rainfall values of Shahat station, so that the most suitable predictors are chosen from the atmospheric forecasts through the regression model. Multilinear, using a combination of correlation matrix, partial correlation and P-value, graphs, and scatterplots.

Table 1. Prediction variables of the QCM general circulation model

No	Predictor variables	predictor description	No	Predictor variables	predictor description
1	mslpaf	mean sea level pressure	14	p5zhaf	hpa divergence500
2	p_faf	surface air flow strength	15	p8_faf	hpa air flow strength850
3	p_uaf	surface zonal velocity	16	p8_uaf	850hpa zonal velocity
4	p_vaf	Surface meridional velocity	17	p8_vaf	850hpa meridional velocity
5	p_zaf	surface vorticity	18	p8_zaf	hpa vorticity850
6	p_thaf	surface wind direction	19	p850af	hpa geopotential height850
7	p_zhaf	surface divergent	20	p8thaf	hpa wind direction850
8	p5_faf	500hpa airflow strength	21	p8zhaf	hpa divergence850
9	p5_uaf	500hpa zonal velocity	22	pr500af	Relative humidity at 500hpa
10	p5 _vaf	hpa meridional 500velocity	23	pr850af	Relative humidity at 850hpa
11	p5_zaf	500hpa vorticity	24	rhumaf	Near surface relative humidity
12	p500af	500hpa geopotential height	25	shumaf	Surface specific humidity
13	P5thaf	500hpa wind direction	26	tempaf	Mean temperature at 2 meter

Source: Wilby and Dawson (2007) p. 17.

8.3 **Calibrate Model**.

The calibration model process builds downscaling models based on the multiple linear regression equation. Given daily weather data (the forecast), regional variables, and the atmosphere (the forecast). The parameters of the regression model are written in a file with the extension (PAR). The calibration model process takes a user-defined prediction along with a set of predictor variables, computes the parameters of multiple linear regression equations via a simple efficient binary algorithm (forced input method) (Wilby, 2007, p. 18)), and then defines the structure of the model using Suitable forecasters had a strong correlation with the rainfall rate at Shahat Meteorological Station.

And by examining the variables, it became clear that there are eight variables out of 26 variables that are closely related to the simulation of rainfall at Shahat Meteorological Station - Table (2). The relationship between vorticity 850hp and the rainfall rate at Shahat Meteorological Station represented the highest correlation value of 0.339. Shown as Figure (2).

Table 2: shows the eight variables of the (GCM) model that are related to the rainfall rate at Irsad shahat station.

order	code	N	correlation
18	p8_zaf	hpa vorticity850	0.339
11	p5_zaf	hpa vorticity500	0.33
5	p_zaf	surface vorticity	0.289
23	pr850af	Relative humidity at 850hpa	0.277

3	p_uaf	surface zonal velocity	0.231
15	p8_uaf	hpa zonal velocity 850	0.224
15	p8_faf	hpa air flow strength850	0.222
9	p5_uaf	hpa zonal velocity500	0.197

Source: The researchers' work based on: SDSM4.2.9.

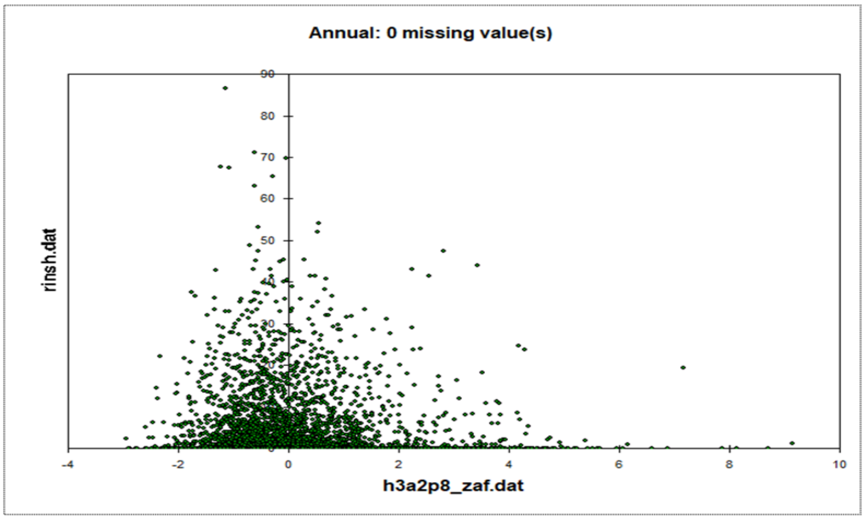

Figure 2: The correlation between element 18 of the (GCM) and the rainfall rate at Shahat Meteorological Station.

Source: The researchers' work based on: SDSM4.2.9.

8.4 Scenario generation

The scenario generation process produces combinations of synthetic daily weather series taking into account atmospheric forecast variables provided by the GCM (to generate a climate period excluding the observed period [8]. At this stage, two scenarios were generated to predict future thunderstorms using (HadCM3) scenarios represented by (A2a & B2a).

8.5 Summary Statistics

Scenario generation files produce multiple or infinite values, so we must summarize them statistically from the (Summary statistics) icon, and then convert them into Excel files to make it easier to deal with them through different statistical programs.

8.6 Verify the accuracy of the Calibrate Model

Before starting to model the rainfall in Shahat for the future periods (2010-2039), (2040-2069) and (2070-2099), we worked on modeling data for a previous period, and the period from (1991-200) was chosen, where the rain data in Shahat was modeled. According to each scenario (A2a, B2a), and compared with the rainfall data of the Shahat meteorological station recorded by the National Center of Meteorology in Tripoli. The result was: the data of the annual rates recorded by the National Center matched the scenario A2a, if the average rainfall according to them was (531.8 mm), while the optimistic model B2a predicted (561.2 mm). On the monthly level, the differences in rates ranged between (-0.2). 13.4 mm). Which indicates the accuracy of modeling by SDSM and its closeness to predicting reality, even if there are some differences on the monthly level. The agreement on the annual level assures us of the accuracy of the prediction. While the reason for the mismatch on the monthly level is due to inaccurate measurement or lack of data recording in some months of the year. It was accepted by the observers at the Shahat station, or it was written down by mistake by the Climate Department of the National Center of Meteorology in Tripoli. Figure (3).

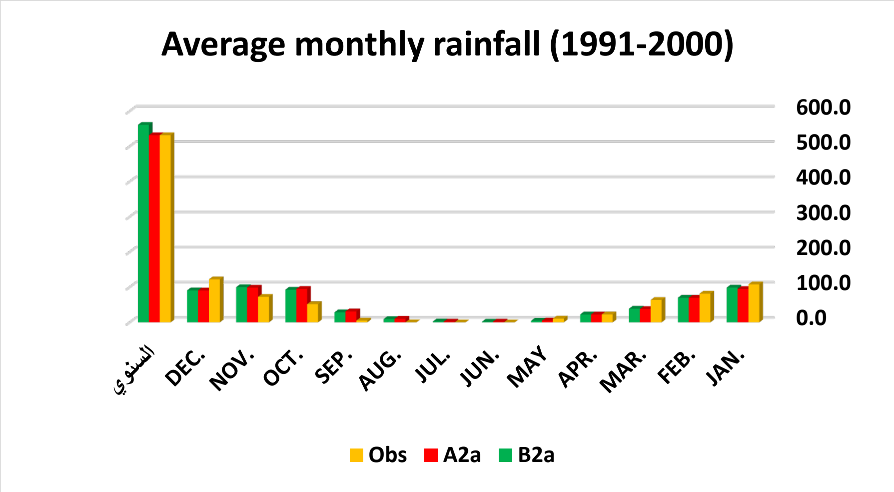

Figure 3: Checking the accuracy of the model.

Source: The researchers' work based on: SDSM4.2.9.

9.0 The second topic Change in rainfall rates at Shahat Meteorological Station for the period (1961-2099)

- First: The change in the monthly and annual rainfall rates at the Shahat meteorological station.

The results of Table (3) show that the rainfall tends to decrease in the future periods compared to the base period (1961-1990), in which the average rainfall was about (574.6 mm), while the average rainfall decreases in the period (2010-2039) to reach (356.7 mm). while it returns to rise in the period (2040-2069) to reach (460.5). Its rate of decline is due in the period (2070-2099) to reach (414.9 mm). As for the monthly level, it is clear from the table that the rainfall rates tend towards an increase in their rates during the months (September, October, November, May, June, July, August). They tend to decrease in the rest of the months clearly Figure (4).

Table 3: Change in rainfall rates in Shahat for the period (1961-2099) according to (A2a &B2a).

Month	1961-1990	2010-2039		2040-2069		2070-2099	
	average	A2a	B2a	A2a	B2a	A2a	B2a
September	12.0	36.7	32.8	21.7	20.9	39.8	37.5
October	59.4	62.1	65.5	57.3	61.2	82.8	89.1
November	61.9	77.2	73.0	77.5	76.5	89.1	85.3
December	113.5	43.8	46.5	69.4	61.7	60.4	45.0
January	128.1	30.7	42.0	78.2	78.6	50.6	45.2
February	92.0	19.3	18.1	62.7	60.8	20.7	26.8
March	68.5	28.3	25.7	42.5	44.0	26.9	23.6
April	28.2	31.5	33.4	28.8	29.8	21.6	23.0

May	6.5	8.7	8.6	6.5	6.2	6.8	6.2
June	2.2	5.1	4.5	3.0	3.6	4.0	4.1
July	0.6	4.9	4.8	2.6	1.9	4.3	4.3
August	1.5	8.3	7.1	10.3	10.6	7.9	8.2
annual	**574.6**	**356.7**	**362.1**	**460.5**	**455.8**	**414.9**	**398.3**

Source: The researchers' work based on: SDSM4.2.

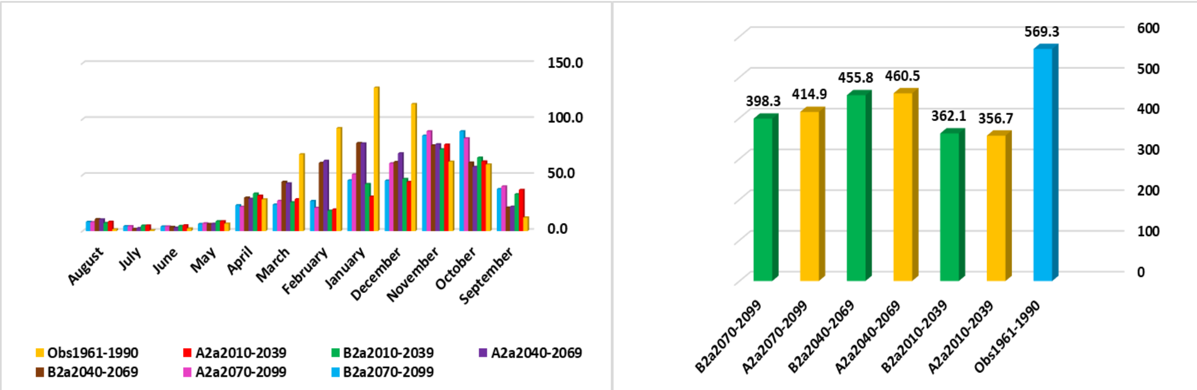

Figure 4: Change in rainfall rates in Shahat for the period (1961-2099) according to (A2a &B2a).

Source: the work of the researchers based on Table (3).

10.0 Second: Change in seasonal rainfall rates at Shahat Station

The results of modelling rainfall at Irsa Shahat station, according to the presented scenarios, indicate that the seasonal rate will witness a change in the rainfall seasons, as the trend of rain will take an upward trend, like two scenarios (A2a, B2a), in the fall and summer seasons, as it increases, respectively (42, 23)., 78.3 mm) to reach the end. While the increase in the summer season, respectively (13.9, 11.6, 11.9 mm). The rainfall rates will witness a clear decrease in the future periods compared to the base period in the winter and spring seasons, as shown in Table (4) and Figure (5). As the decrease for the winter season in the three periods in a row at a rate of (239, 127, 302 mm). In the spring, the decrease for future periods is (262, 252, 275 mm).

Table 4: Change in seasonal rainfall rates Shahat for the period (1961-2099) according to (A2a & B2a).

Season	1961-1990	2010-2039		difference	2040-2069		difference	2070-2099		difference
	Average	**A2a**	**B2a**		**A2a**	**B2a**		**A2a**	**B2a**	
Autumn	133.4	176.1	171.4	+42	156.5	158.6	+23	211.7	211.9	+78.3
Winter	330.5	90.8	103.1	-239	203.5	194.7	-127	127.4	113.3	-203
Spring	330.5	68.5	67.7	-262	77.8	79.9	-252	55.3	52.8	-275
Summer	4.3	18.3	16.4	+13.9	15.9	16.1	+11.6	16.2	16.5	+11.9

Source: The researchers' work based on: SDSM4.2.9

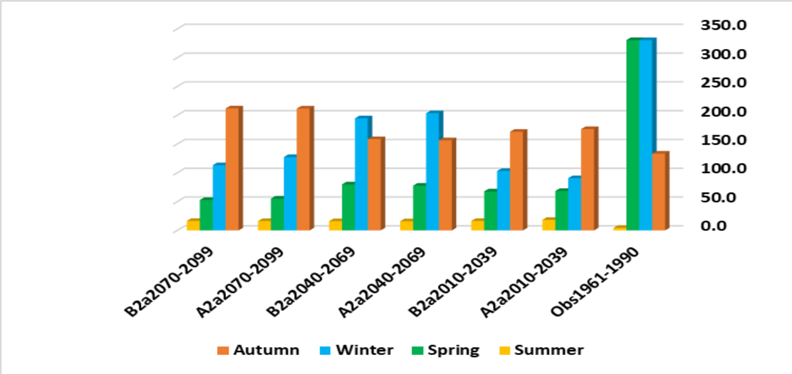

Figure 5: Total monthly rainfall in Shahat for the period (1961-2099) according to (A2a & B2a).

Source: the work of the researchers based on Table (4).

11.0 Discuss the results

The SDSM tool proved its accuracy in predicting the future of rainfall at the Shahat meteorological station when the annual average data recorded by the National Center matched the A2a scenario if the average rainfall, according to them, reached (531.8 mm). This indicates the accuracy of modelling by SDSM and its closeness to predicting reality, even if there are some differences on the monthly level, so the congruence on the annual level confirms this accuracy of prediction.

The rainfall rates at Shahat Meteorological Station are associated with eight elements of the general circulation model (GCM). The relationship between vorticity 850hp and the rainfall rate at the station represented the highest correlation value of 0.339.

Rainfall rates at the station witness a general trend of decreasing for the three modelling periods compared to the base period. This is consistent with all IPCC scenarios, and the attrition rate is consistent with scenarios A2a and B2A. This warns of the inability of the countries of the world to control and mitigate emissions of greenhouse gases. This is consistent with the Arab report [9]. According to RCP4.5- 8.5 scenarios. The brown colour in the east of the country, where the Shahat region is located, indicates that it will be exposed to drought in future periods because of the decrease in rainfall Figure 6.

The period from (2010-2039) witnessed a decrease in the average rainfall to reach (356.7 mm), with an estimated difference of 218 compared to the base period.

The results of the modelling proved that there is a change in the seasons and amounts of rainfall, as the amounts of rainfall will increase in the fall and summer seasons, while it decreases significantly during the winter and spring seasons. This is consistent with the future modelling of temperatures. (Al-Mulyan et al. in 2021) confirmed [10] that the temperature tends to rise in the winter and spring seasons and tends to decrease in the autumn and summer seasons.

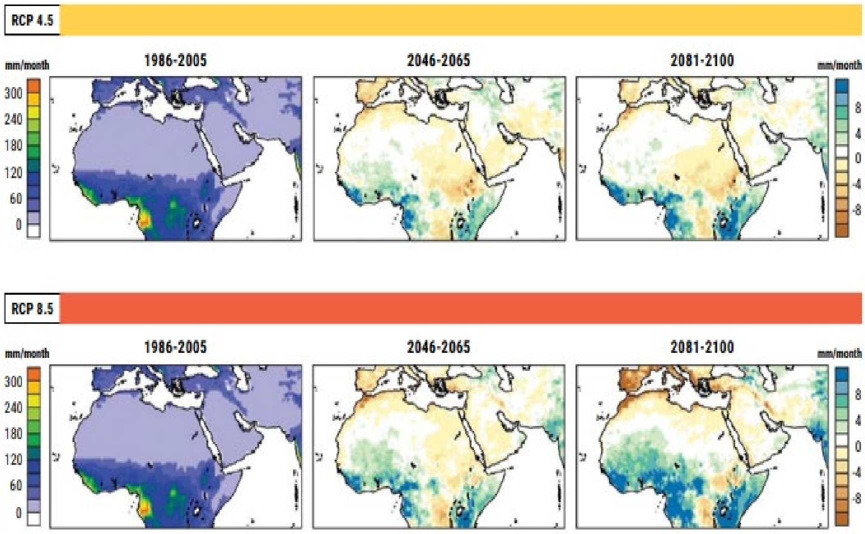

Figure 6: Mean annual change in rainfall up to 2100 using RCP4.5-8.5 scenarios.

Source: Arab Report on Climate Change Assessment, 2017, p. 63.

12.0 Recommendations

- The apparent decrease in rainfall rates, especially in the winter and spring seasons, portends several risks resulting from climate change during the coming years, and Libya is one of the country's most vulnerable to these risks, especially with regard to agricultural activity.
- Decision makers must take the necessary and urgent measures to confront these risks, such as devastating heat waves and drought that coincides with the scarcity of groundwater in all regions alike, in addition to the extension of desertification and the loss of soil fertility and characteristics, which will have a significant impact on agricultural lands and crops. Therefore, it is necessary to raise awareness of these risks and rationalize water to reduce drought and desertification.
- The Libyan state must undertake the necessary maintenance of roads and roads, as the increase in rain services outside the season and its length in large quantities in a record time may not result in major floods.
- The government must attach great importance to supporting scientific research projects that advance the first-level fields in this field and that focus on providing advanced technology in studying those different areas of intense rain, which portends floods in the future.
- It should be noted that it contains sound monitoring methods, thanks to advanced skills and measurement, along with developing capabilities and increasing the efficiency of its work, to obtain accurate and correct climate data that supports scientific research, and to formulate scientific advice that will quickly take the appropriate decision.

13.0 Acknowledgement

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