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Prediction of Rainfall of Haifa Using MLR and ARIMA Models

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ABSTRACT

This study was conducted to predict the rain fall of Haifa the third largest city of Israel with a population around 285,300 people, which is a part of a sizable metropolis with 962,500 inhabitants and is situated on a bay in the northeastern Mediterranean Basin. The city is a representative of a number of Mediterranean sub-climatic areas due to its distinctive sea-land meteorology and complex hilly topography.

In order to get the best fit based on the best distribution value, this work aims to develop combining strategies for rainfall prediction in Haifa based on ARIMA and MLR models. This will aid farmers in making agricultural decisions, hydrological department water storage decisions, and analysis of groundwater level decisions. It was conducted using of Modeling of monthly precipitation using MLA and ARMA including the best distribution graphic produced by the model and to find the best fit of various distributions displayed by the models which displaces the smallest value of AD. The data obtained and used in this study are monthly rainfall satellite data from Terraclimate using Haifa, the third largest city of Israel from 1958-2020 (62yrs) time interval.

Result shows that long-term continuous data forecasting, the ARIMA model outperforms the MLR models. By its efficiency and precision, ARIMA may be a more appealing option to MLR. As the numerous numbers show, there isn't much of a distinction comparing ARIMA and MLR models. The Logistic distribution plot is the best fit or recommended distribution. From the summary displaced, it can be seen from the numerous distribution plots used to decide which the best match for histogram exhibition is. The best-fit distribution plot has the lowest AD value.

Using precipitation as one of the factors to determine which distribution plot is the best as displaced in the summary table of the AD values of the various plots, it was evaluated that the best fit is the distribution function of the Probability Plot of ppt (mm) of Logistic parameter with the smallest AD value of 59.435 which has the lowest AD value in the Different parameter distribution plots.

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1. INTRODUCTION

In the world today, predicting rain is a difficult endeavor. Since precipitation and climate are very complicated and nonlinear processes, accurate computer simulation and modeling were needed. It offers a study and survey of several procedures in the literature that can be used to apply different regression techniques for predictions used by various researchers. This model identifies a rainfall prediction system that is more effective than antiquated techniques. The effects of global warming are getting more pronounced; hurricanes, drought, wildfires, and floods have all become more intense and frequent. Global ecology is changing, and this includes the agricultural and natural resources that support civilization. A 2018 multinational assessment on global warming concluded that the planet faces catastrophic consequences if anthropogenic greenhouse gas emissions are not eliminated in 30 years.

Regardless of the fact that there is a worldwide problem with global warming, national governments set regulations to control carbon dioxide emissions (GHG). If there isn't a worldwide body to oversee and implement universally ideal climate policies, leading goers must demonstrate taking the lead by endorsing bold climate goals. By reducing the cost of key technologies, proving the viability of the transition to clean energy, and exerting greater political pressure placed on ineffective administrations unwilling to make a contribution to the global public good of reducing climate change, these leading contenders have the potential to accelerate global climate efforts [19]. Unilateral actions, on the other hand, have ramifications for other countries and areas in a globalized trade [20]. Sharp disparities in emission reductions between regions and countries create concerns that laggards may benefit from decreased electricity prices associated with prolonged fossil fuel use ([21]. For example, energy-intensive firms may rapidly relocate to areas with laxer climate rules in order to avoid paying higher rates need more electricity that is clean tightly controlled areas. This so-called "carbon leakage" has the prospective to undercut the smallest of some of the abatement rules put in place by the leading contenders [21]. Dechezleprêtre & Sato [22] found little verifiable research that environmental laws have a negative impact on enterprises' competitive.

This is due to the fact that energy prices account for a small percentage of overall manufacturing costs in most industries, with companies prioritizing other factors such as accessibility to key markets and a reliable formal context, or an experienced workforce. Furthermore, trade costs limit industry migration [25], which may be especially important with large energy-consuming products like steel, aluminum, or cement. Energy-intensive businesses have regularly profited from some type of leaking prevention in nations or areas that have undertaken strong climate measures.

Rainfall is the accumulation of raindrops from atmospheric water vapor that have become heavy enough to fall. Rain plays a vital role in the water cycle since it deposits the bulk of the world's freshwater supplies. Climate change has the ability to influence the duration and intensity of rainfall. Oceans that are relatively warm evaporate more water into the atmosphere [19]. As it flows over land or converges into a storm system, more condensed air can produce more intense rainfall, such as larger rainfall events. Crop loss, soil erosion, and an increase in flood risk as a result of heavy rain are all key effects of extreme rainfall, which can result in accidents, accidental deaths, and other flooding-related health issues. Rainfall discharge can also affect the environment.

The interaction between these factors determines the climate of the Mediterranean region, the circular regimes of the middle and subtropical latitudes and the complex morphology of the mountain ranges and the contrast between land and sea. These exceptional conditions make this region one of the most significant climate change hotspots in the world [23-24]. Climate change hotspot is a decrease in rainfall expected, in contrast to an overall increase in the water cycle. Presently, the average temperature increase across the basin is 20% larger than the average global warming and warming trends, such as prolonged hot summers, frequency and intensity of heat wave increases, changes in rainfall patterns and decreases rainfall. Additionally, recent projections in the Mediterranean for the foreseeable future region indicate that heat waves, droughts and floods are likely to be more frequent events [26] Weather prediction models are computer programs that can forecast the weather for any time period in the future, ranging from an hour to ten days and even months.

Haifa's water supply is made up of both conventional (surface and groundwater) and unconventional (seawater desalination, desalination of seawater, reuse of treated wastewater, etc.) water sources [19]. Being situated on the northwest tip of Mount Carmel gives Haifa-A, which makes up around 20% of the entire municipal water distribution network, a noticeable array of landscape: the bottommost connection is only 5 m overhead mean sea level, while the highest has an elevation of 240 m. This pipeline pumps water to the upper heights [19]. Haifa-A can handle roughly 13,000 m3 per day, peaking at 21,000 m3 per day [19]. Peak demand in Hawaii is estimated to be around 60,000 people, whose daily average consumption amounts to around 10% of the peak daily demand, or 2100 m3 per hour. 12,900 m3 of total capacity are available, which is 61 percent of the per day peak demand. The remaining 3750 m3 of capacity are shared by the remaining 5 DMAs. 13 of the 17 pumps, which are distributed among 5 pumping stations, are actively working; the other

6 are on backup. However the system doesn't have any remote-control valves, it's the one that closes whenever the Mahane-David (MD) pumping station is turned on [19].

In order to get the best fit based on the best distribution value, this work aims to develop combining strategies for rainfall prediction in Haifa based on ARIMA and MLR models. This will aid farmers in making agricultural decisions, hydrological department water storage decisions, and analysis of groundwater level decisions. It was conducted using of Modeling of monthly precipitation using MLA and ARMA including the best distribution graphic produced by the model and to find the best fit of various distributions displayed by the models which displaces the smallest value of AD.

2. RESEARCH METHOD

Study Area (**Haifa 1958-2020)**

Around 285,300 people live in the Israeli city of Haifa, which is a part of a sizable metropolis with 962,500 inhabitants and is situated on a bay in the northeastern Mediterranean Basin [27]. Israel's third-largest city is Haifa, behind Tel Aviv and Jerusalem. Haifa Bay has evolved in to the Israel's main industrial area since the early 1930s. Since the creation of the State of Israel in 1948, the Haifa Municipal government has been in charge of running the city. As of 2016, the city, which occupies 63.7 km2 in the Bay of Haifa, is a significant harbor on Israel's shoreline (24.6 sq mi). Approximately 90 km (56 mi) north of Tel Aviv, it is the main central hub in northern Israel. The city is representative of a number of Mediterranean sub-climatic areas due to its distinctive sea-land meteorology and complex hilly topography [28]. Additionally, the city's population is different in several ways and contains Jews (76 percent), Arabs who are Muslims and Christians (12 percent), and others. It also includes locals and recent migrants, religious and nonreligious individuals, individuals of different years, and people from dissimilar socioeconomic backgrounds. As a result of the country's changing climate, Israel has seen an increase in the frequency and magnitude weather events [6]. In the recent past, Haifa has suffered serious rising temperatures (e.g., May 2019; September 2020), two sizable wildfires (2010 and 2016), and winter floods (e.g. December 2019; January 2020) [9]

Additionally, the city's population is diverse in many other ways. The winters in Haifa are mild, moist, and mainly clear, while the summertime there are warm, muggy, dry, and clear. The average annual temperature ranges between 50°F and 87°F, rarely falling below 44°F or rising over 90°F.The highest period of year to holiday Haifa for warm activities, according to the beach/pool score, is from early June to mid-October.

Figure 1. Map of Haifa (study area)

Source: Google Map

2.1. Dataset (Terraclimate)

The satellite data was used in this study due to lack of the ability to get actual rainfall data from the study area. Furthermore, satellite data obtain from Terraclimate use for modeling precipitation or rainfall using ARIMA and MLR haven proven to be accurate or close to approximation when compare with the actual rainfall data other studies. While researching the accuracy of the Box-Jenkins statistical method to predict the share price performance for the oil and gas industry in Malaysia, Abu Bakar and Rosbi (2017) discovered that the performance of Gas Malaysia Berhad can be accurately predicted using the Autoregressive Integrated Moving Average (ARIMA) model of (5,1,5). Similar to Malaysia, Balli and Elsamadisy (2012) try comparing the linear techniques and find that in the State of Qatar, the seasonal ARIMA model yields better estimates for short-term projections. For the projections of short-term currency in circulation (CIC), the seasonal ARIMA model's range of forecast errors is fewer than 100 million Qatari

Riyals. For example, weather conditions play an important role for aviation and logistics companies in planning the fastest and safest flight routes. Therefore, many different weather models have been developed and applied all over the world. In this blog post, we show how we developed a neural network to predict precipitation in a given area based on infrared satellite data.

2.2. Advantages of Terraclimate

Using a water balance model that incorporates evaporation, precipitation, basal temperature, and the interpolation of soil water that plants may extract, Terraclimate also creates monthly surface water balance information. Studies on hydrology and ecology at a global scale can benefit greatly from these data. Data sets that are geographically and temporally consistent are necessary for global environmental challenges that attribute a particular phenomenon to climate. In addition to datasets that interpolate data from surface observations1, reanalysis, and various combinations of them, there is a sizable and expanding collection of historically observed climate data sets. Each dataset offers the benefit of the variables provided, including temporal and spatial resolution, as well as geographic ranges and time periods. Through a limitless database provided by the Northwest Knowledge Network at the University of Idaho, Terraclimate is accessible to the general public. The Terraclimate dataset shows significant enhancement in global In comparison to grid datasets with lower resolution, mean absolute error and spatial realism have increased.
Disadvantages of Terraclimate

1. Long-term data trends are inherited from the parent data set. Terraclimate should not be used directly for independent trend assessment.
2. Terraclimate will not capture variation over time at scales better than the parent data sets and therefore cannot capture changes in the rate and inversion of geological precipitation.
3. The water balance model is simple and does not take into account the heterogeneity of vegetation patterns or their physiological responses to changing environmental conditions.
4. Validation is limited to regions where data is scarce (e.g. Antarctica).

2.3. Models

A statistical technique called multiple regression analysis, or MLR, combines a set of parameter estimates to forecast a response variable's result.
Multiple linear regressions are used to attempt to show the linear connection among the descriptive (independent) and response (dependent) variables. Due to the inclusion of several explanatory variables, multiple regressions are basically an extension of ordinary least-squares (OLS) regression.

$$Yi = \beta 0+\beta 1xi1+\beta 2xi2+...+\beta pxip+\epsilon$$

Where for *i*=*n* observations:

yi =dependent variable

xi =explanatory variables

$\beta 0$ = y-intercept (constant term)

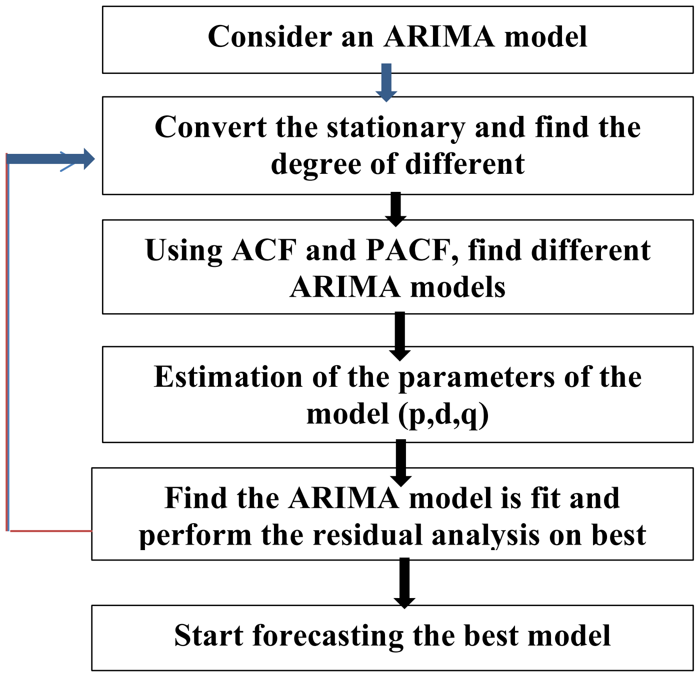
βp = slope coefficients for each explanatory variable

ϵ = the model's error term (also known as the residuals)

Using information from another variable, a statistician or analyst can apply basic linear regression to create predictions about one variable. Only 2 consecutive parameters x2 and a dependent variable—can be utilized in linear regression. The characteristic utilized to calculate the response variable or result is known as the independent variable. The explanatory variables in a multivariate regression model are numerous. To calculate how much of the variance in the independent components can be accounted for by the variance in the results, statisticians utilize the coefficient of determination (R-squared). Even if the predictors are unrelated to the outcome variable, R2 always increases when additional indicators are added to the MLR model. R2 can't be used by itself to decide which predictors should be integrated into a model and which ones should be left out. Only the numbers 0 and 1 can be used to express R2, where 0 denotes that none of the independent variables can reliably predict the outcome and 1 denotes that all of them can. The results of multiple regressions are interpreted via beta coefficients.

Autoregressive Integrated Moving Average

A time series extension of the auto-recovering integrated moving average (ARMA) pattern is the self-healing integrated moving average (ARIMA) pattern. In order to better comprehend or forecast upcoming opinions in the series, both of these models are used to fit time series data (forecast). When there are indications of mean-direction instability in the data but no variation or self-change, the ARIMA model is employed. To remove the mean function instability (i.e. trend), the first stage of difference (corresponding to the "built-in" element of the model) can be applied once or more. When a time series exhibits periodicity, the seasonal difference can be utilized to eliminate the seasonal component. The model in which a growing variable self-regresses to its own lag or to its previous values is called auto regression (AR). The term "integrated" (I) refers to the difference between the examined factors that causes the time series to become static (i.e., the gap between the datasets is used to substitute the data values and the prior values). Moving average is used to integrate the relationship between the observation and residual error of the lagged moving average model (MA). Each element in variable ARIMA is regarded as a standardized name. For ARIMA models that employ integer values instead of parameters to denote the type of ARIMA model being used, ARIMA with p, d, and q is a typical expression. The parameters are as follows: p: the order of the delay model; sometimes called the number of lag explanations. D: degree of difference; also known as the number of times the raw observations differ. Many statistical models, especially ARIMA time series models, can be thought of as a way to turn data into white noise or a series of uncorrected errors. This unpredictability can be calculated straight after the explanations if the parameters are known with precision; when the actual values of the parameters are substituted for the estimates, the resulting sequence is called the "residual", which can be viewed as approximate errors. There would be no autocorrelation in the errors if the correct model was applied. Therefore, it is reasonable to investigate the residuals' samples autocorrelation functions while determining the fit.



Flow chart of ARIMA model

2.4. Data Set

Model Assessment

The third-largest city in Israel, Haifa, provided the continuous average daily traffic data that were used in this study. Terraclimate is used to generate the data. Data from the station span 62 years, from 1958 to 2020. The traditional MLR approach of the data used to derive the MLR equation between precipitation and the remainder was used to validate the equations was the initial model for the investigation. Distribution functions of various Probability Plot ppt (mm) were used to determine the best fit of the distribution function. The distribution function of Probability Plot ppt (mm) of Logistic distribution with an AD value of 59.345 was selected as the best fit based on it containing the smallest AD value. It's indicated that, the smallest the AD value, the better it fits the model for the prediction of the rainfall.

2.5. Minitab

The tools Mini Tab and MLR were used to determine the relationships between the variables (MLR). A statistical program for data analysis is called Minitab. It provides an easy way to enter statistical data and spot patterns and trends in the data. Both statistical techniques and simple infographics are available in Minitab. It offers an immediate and viable method but calls for intense analysis. These are typically tools for process improvement, statistical analysis, and data analysis.

R-squared

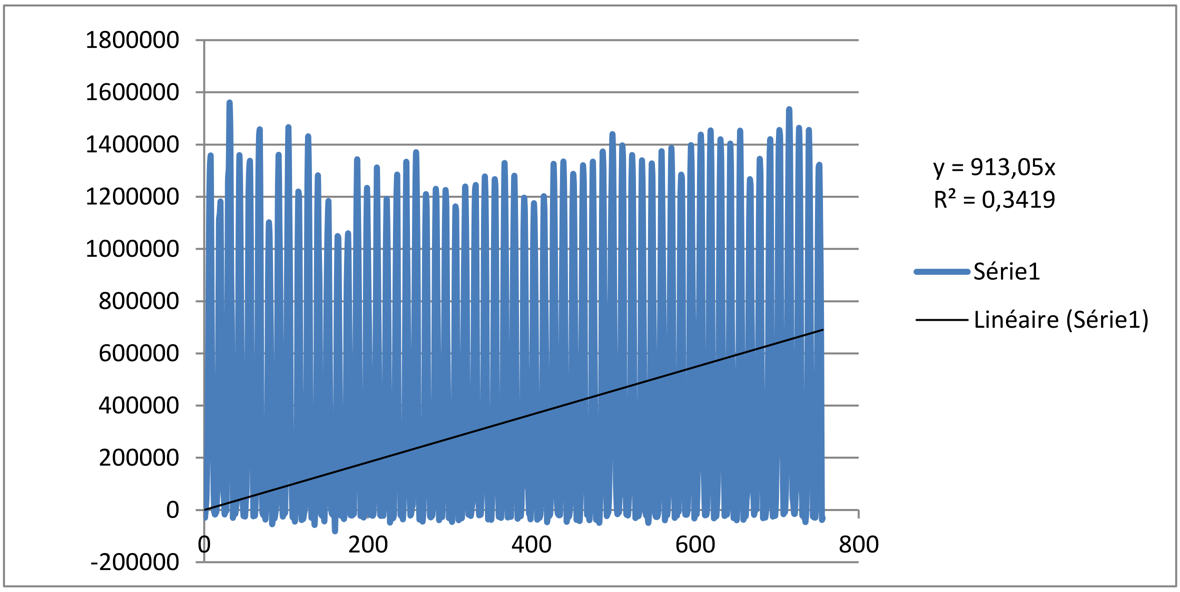
R-squared, abbreviated as R2, is a statistical measure that represents the amount of change in a dependent variable that can be attributed to one or more independent variables in a percent regression model. R-squared is a regression evaluation metric that examines the dispersion of data points around a fit regression line and describes how well the variance of one variable explains the variance of the second. R squared is a statistic used in the evaluation. It takes into account the part of variance attributed to the dependent variable. Therefore, if the R2 of a model is 0.50, it means that the model inputs can describe about half of the variability.

$$R^2 = \frac{\text{Variance explained by the model}}{\text{Total Variance}}$$

Therefore, you as a user need to regularly test R2 in combination with other variables before drawing any conclusions about the regression model. The mean of the dependent variable contributes to both the dependent variable prediction and the regression model. However, % corresponds to a model that explains the variation of the response variable around its mean.

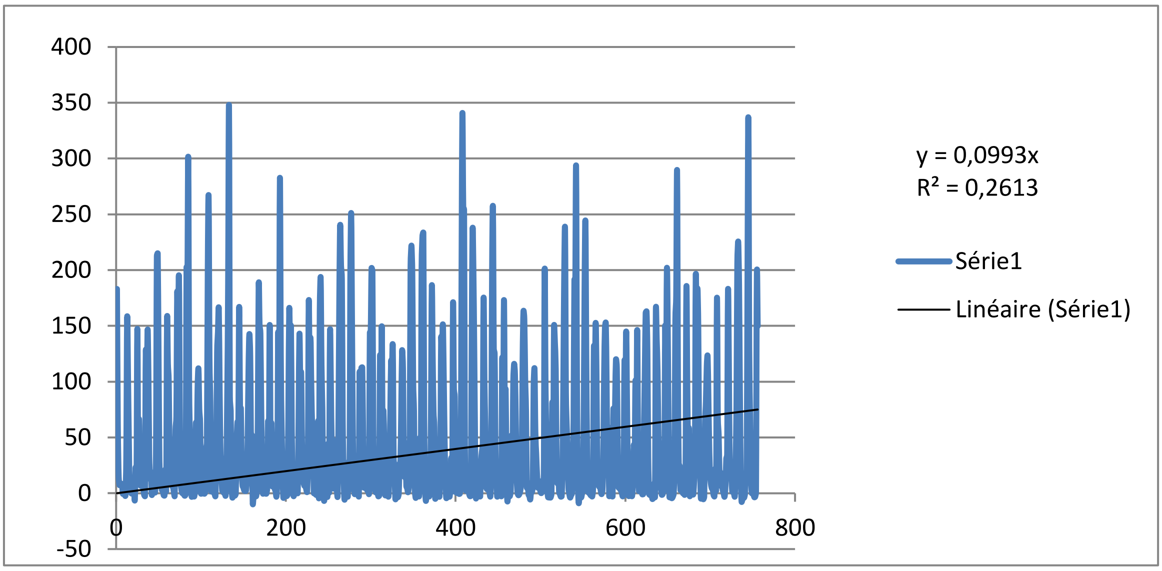
2.6. Multiple Linear Regressions (Haifa) 1958-2020

Graph 1.0 (Value of X$Y-Axis) below shows an R-squared value of 0.16. How well the regression fits the data is shown by the R-squared. The R-squared calculates how much the X parameters (aet, def, pdsi, pet) in the regression model affect the Y variable (ppt). The better the model fits the data, the greater the R-squared score.



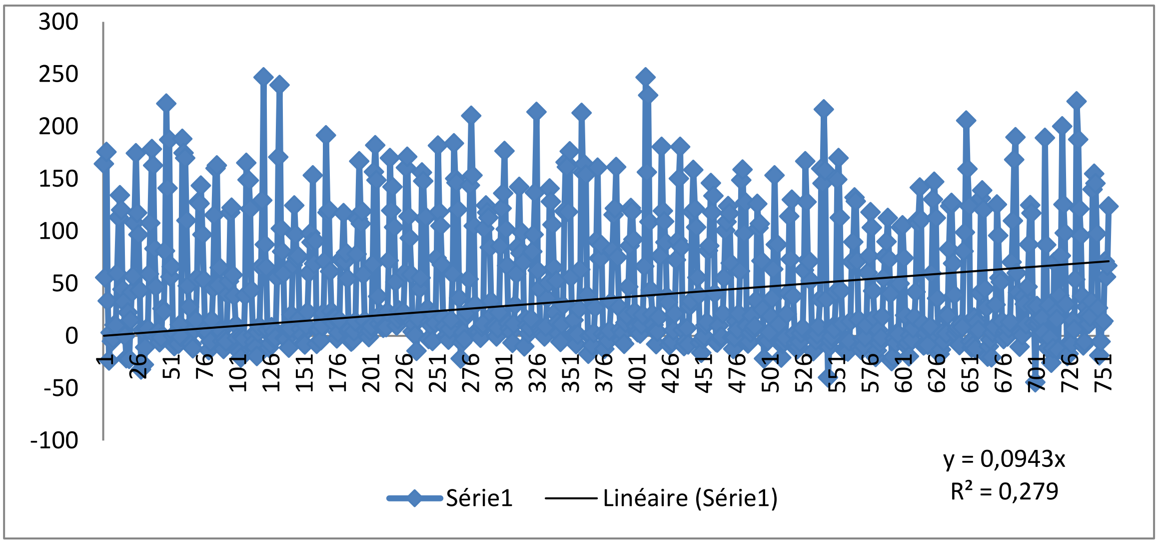
Graph 1.0 (Value of X$Y-Axis) of the Multiple Regression

Graph 1.2 (Value of X$Y-Axis) below shows an R-squared value of -0.129. How well the regression fits the data is shown by the R-squared. The R-squared calculates how much the X parameters (q, soil, sard, and tmax) in the regression model affect the Y variable (ppt). The better the model fits the data, the greater the R-squared score.



Graph 1.2 (Value of X$Y-Axis) of the Multiple Regression

Graph 1.3 (Value of X$Y-Axis) below shows the R-squared value to be -0.21. How well the regression fits the data is shown by the R-squared. The R-squared calculates how much the X parameters (timn, Vap, Vpd, and ws) contributed to the variance of the Variable y (ppt) in the regression model. The better the model fits the data, the greater the R-squared score.



Graph 1.3 (Value of X$Y-Axis) of the Multiple Regression

In order to interpret an ARIMA analysis, take the following actions. Significant outcomes include the p-value, coefficients, mean square error, and Ljung-Box chi-square statistics. The coefficient is statically important if the p- rating is lower than or equal to the level of significance. You cannot draw the conclusion that the coefficient is statistically significant when the p-rating is higher than the importance level. It would be a good idea to remove and then restore the term from the mode.

Table 1. Below shows the Concluding Estimations of the Parameters (Coef, SECoef, T, and P respectively)

Type	Coef	SE Coef	T	P
AR 1	-0.7444	0.0358	-20.77	0.000
AR 2	-0.2744	0.0360	-7.63	0.000
SAR 12	-0.7400	0.0348	-21.26	0.000
SAR 24	-0.4060	0.0348	-11.68	0.000
SMA 12	0.9654	0.0140	69.16	0.00
Constant	0.0172	0.1052	0.16	0.870

```
Differencing: 1 regular, 2 seasonal of order 12
Number of observations:  Original series 756, after differencing 731
Residuals:    SS = 2408377 (back forecasts excluded)
              MS = 3322 DF = 725
```

Table 2. Modified Box-Pierce (Ljung-Box) Chi-Square statistic.

Lag	12	24	36	48
Chai-Square	70.0	97.2	137.4	157.9
DF	6	18	30	42
P-Value	0.000	0.000	0.000	0.000

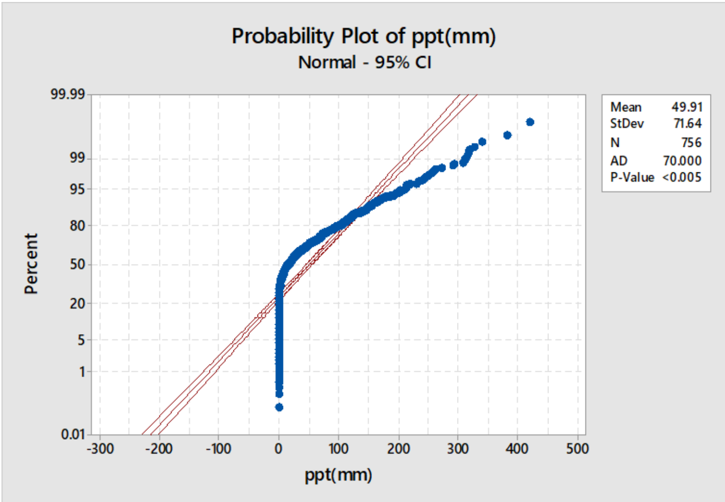


Figure 2. blow shows the distribution function of Probability plot of ppt (mm) of Normal-95%CI with an AD value of 70.000 and the Normal Distributions Graph

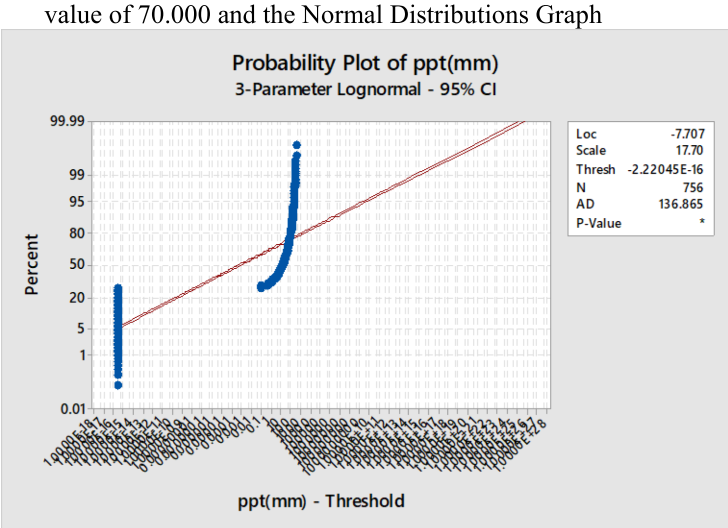


Figure 3. Below represents the distribution function of Probability Plot of ppt (mm) of 3-Paramater Lognormal with an AD value of 136.865 and the distributions graph.

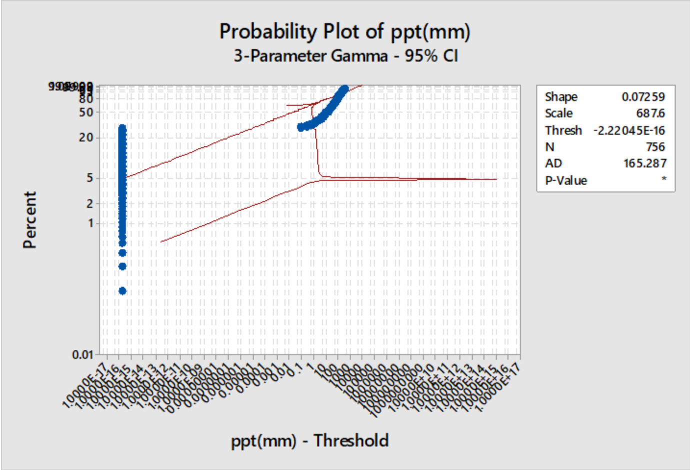


Figure 4. Below indicates the distribution function of the Probability Plot ppt (mm) of 3-Paramater Garma-95%CI with an AD value of 165.287 and the distributions graph.

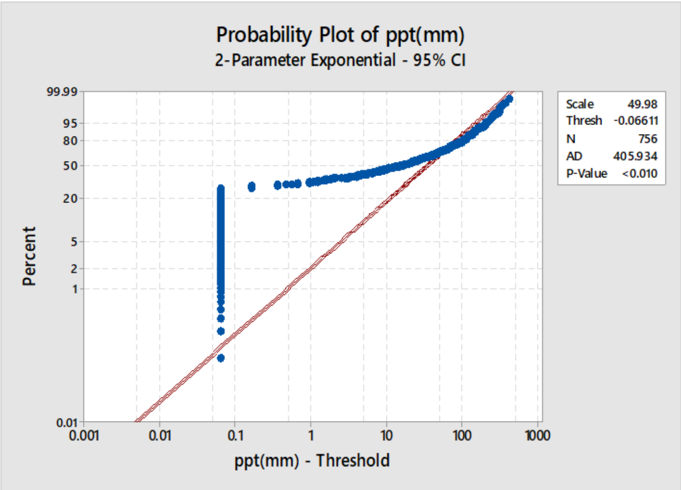


Figure 5. shows the distribution function of Probability Plot ppt (mm) of 2-Paramater Exponential with an AD value of 405.934 and the distributions graph.

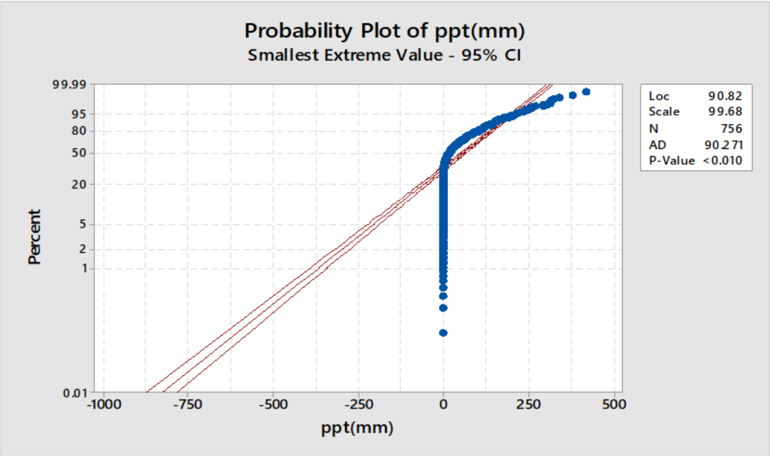


Figure 6. provides the distribution function of the Probability Plot pp (mm) of Smallest Extreme Value with an AD value of 90.271 and the distributions graph.

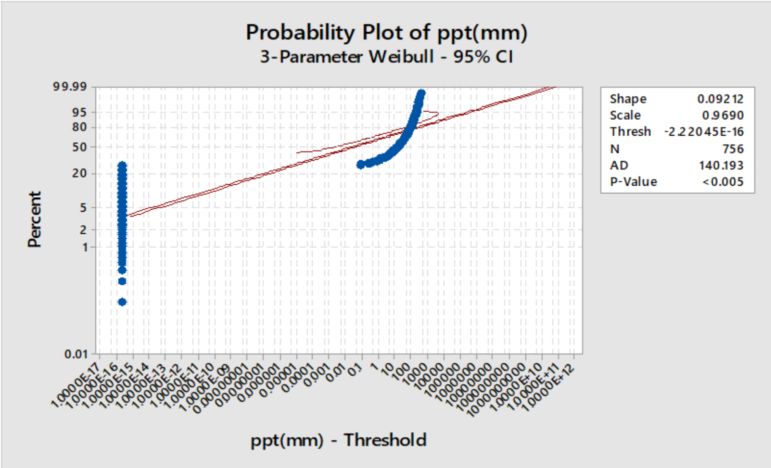


Figure 7. indicates the distribution function of Probability Plot ppt (mm) of 3-Paramater Weibull with an AD value of 140.193 and the distributions graph.

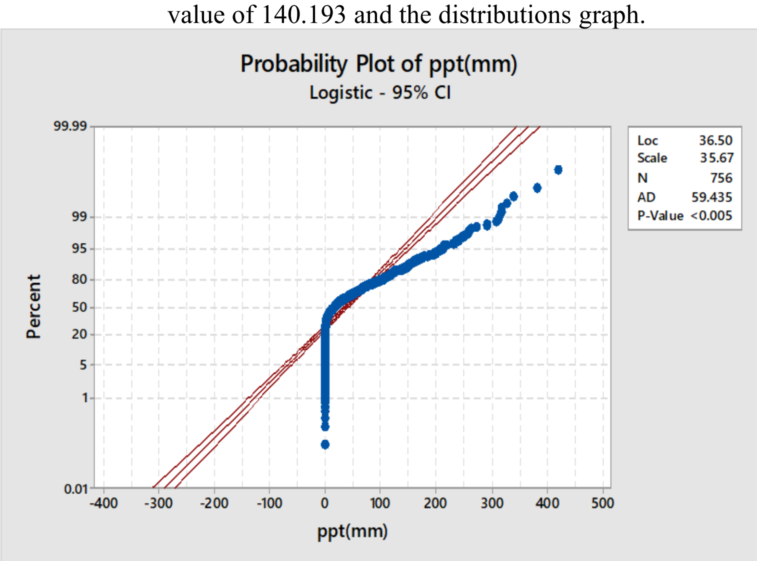


Figure 8. Below shows the distribution function of the Probability Plot ppt (mm) of Logistic Distributions with and AD values of 59.435 and the distribution graph.

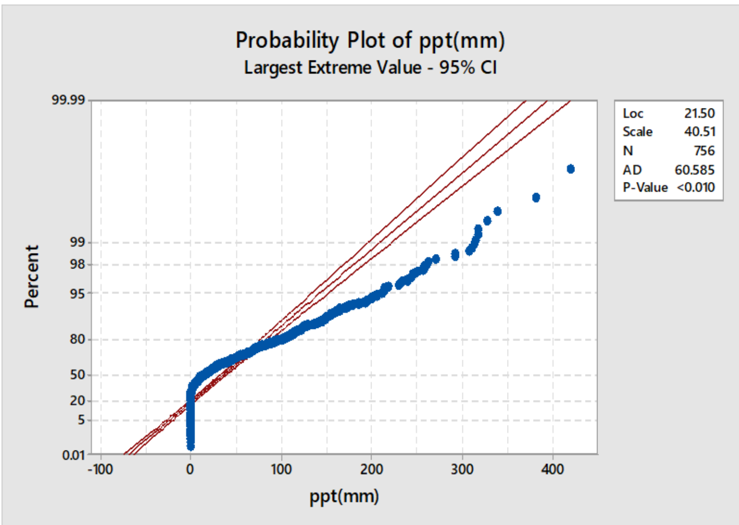


Figure 9. Below provides the distribution function of the Probability Plot ppt (mm) of Largest Extreme Value with an AD value of 60.585 and the distributions graph.

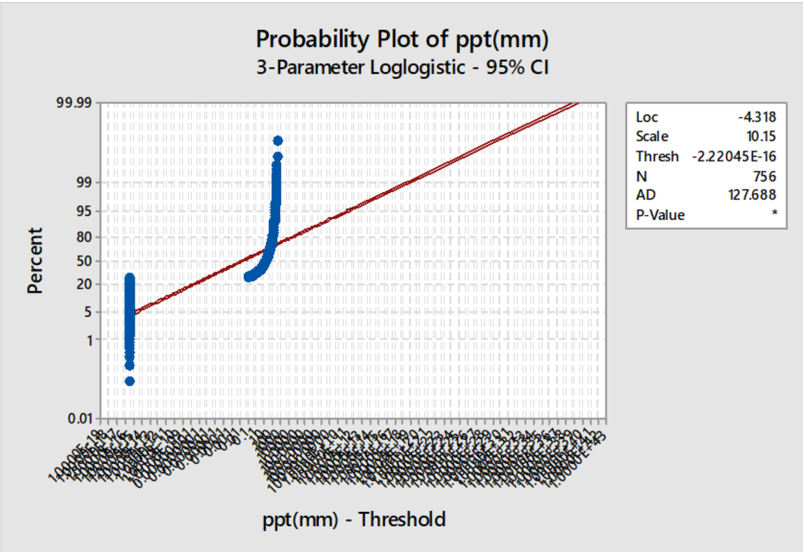


Figure 10. Below shows the distribution function of the Probability Plot ppt (mm) of Largest Extreme Value with an AD Value of 127.688 and the distributions graph.

3. RESULTS AND DISCUSSIONS

Rainfall Distribution using Distribution Functions

The AD-Value, also known as the Anderson-Darling goodness-of-fit statistic, is a statistic that assesses the separation among the tailored lines and the empirical distribution function, which is derived from a normal distribution (that is grounded on the data points). The Anderson-Darling statistic the square of the distance emphasizes the tails of a distribution over the rest of the distribution. Precipitation is one of the factors used to determine which distribution plot is best and has the lowest AD value in the Different parameter distribution plots. We can assess whether the given data can be appropriately characterized by the distribution of the given choice by "fitting" the distribution to the data. The AD-Value, or Anderson-Darling goodness-of-fit statistic, should adhere to the distribution of a histogram. The best fit for the histogram can be determined by looking at the various Distribution plots and their related AD values (shown below). A statistic that calculates the distance between two fitted points

Table 3. Below shows the summaries of the various distribution functions used with an AD values of the various distribution function including the non-fit distributions.

Distribution	AD value	Meaning
Normal	70.000	
Lognormal	N/A	
3-parameter lognormal	136.865	
Gamma	N/A	
3-parameter gamma	165.287	
Exponential	N/A	
2-parameter exponential	405.934	
Smallest extreme value	90.271	
Weibull	N/A	
3-parameter Weibull	140.193	
Largest extreme value	60.585	

Logistic	59.435	**Best Fit**
Loglogistic	N/A	
3-parameter loglogistic	127.688	

Using precipitation as one of the factors to determine which distribution plot is the best as shown in the above summary, it was evaluated that the best fit is the distribution function of the Probability Plot of ppt (mm) of Logistic parameter with the smallest AD value of 59.435 and has the lowest AD value in the Different parameter distribution plots.

4. CONCLUSION

In the world today, predicting rain is a difficult endeavor. Since precipitation and climate are very complicated and nonlinear processes, accurate computer simulation and modeling were needed. It offers a study and survey of several procedures in the literature that can be used to apply different regression techniques for predictions used by various researchers. This model identifies a rainfall prediction system that is more effective than antiquated techniques.

In order to get the best fit based on the best distribution value, this work aims to develop combining strategies for rainfall prediction in Haifa based on ARIMA and MLR models.

. This will aid farmers in making agricultural decisions, hydrological department water storage decisions, and analysis of groundwater level decisions. The data obtained and used in this study are satellite data from Terraclimate using Haifa, the third largest city of Israel from 1958-2020 (62yrs) as the study area.

As can be seen from the modeling section of this article, ARIMA models outperform or fit the MLR method to estimate monthly precipitation in precipitation-related problems. The study's key findings can be stated as follows: For long-term continuous data forecasting, the ARIMA model outperforms the MLR models. By its efficiency and precision, ARIMA may be a more appealing option to MLR. As the numerous numbers show, there isn't much of a distinction comparing ARIMA and MLR models. Using precipitation as one of the factors to determine which distribution plot is the best as shown in the above summary, it was evaluated that the best fit is the distribution function of the Probability Plot of ppt (mm) of Logistic parameter with the smallest AD value of 59.435 and has the lowest AD value in the Different parameter distribution plots

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