CHENNAI WATER CRISIS MANAGEMENT

Sahana S R , Abhishek R ,
2nd year MSc Data Science,
Department of Data science,
Coimbatore institute of technology.

Dr. M. Sujithra ,
Department of Data science,
Coimbatore institute of technology.

INTRODUCTION:

The water shortage in the city of Chennai has been haunting the whole city for the past few months. The city has just faced and is still facing the worst water shortage over the past 30 years. The idea of this project is to generate a forecast model and predict the condition on this city if the situation continues to be the same. The project focuses on only the water that is available from the four main reservoirs of Chennai which contributes about 60% of water needed by the city. As the level of water in these reservoirs are affected by the rainfall during any given period of time, a forecast model which predicts the rain fall is also built. This forecast will be of great help to acquire knowledge about the current and the future scenario of the city in terms of the demand and supply of water.

DESCRIPTION:

Chennai is one of the four metropolitan cities of India and also the capital of Tamil Nadu. Chennai is one of the busiest business hubs in India. It is a city of over 8 million people, around the size of New York City, and is the fourth largest city in India.

The water crisis in Chennai in 2019 has been hitting headlines like never before and the fear that such crisis can happen in several other cities is also rising.

Following are the major sources of water supply for Chennai city.

1. Four major reservoirs in Red Hills, Cholavaram, Poondi and Chembarambakkam
2. Cauvery water from Veeranam lake
3. Desalination plants at Nemelli and Minjur
4. Aquifers in Neyveli, Minjur and Panchetty
5. Tamaraipakkam, Poondi and Minjur Agriculture wells
6. CMWSSB Boreweels
7. Retteri lake

Apart from these, the city also depends on ground water which is replenished by natural rains. People also make use of bore wells and private tankers to meet their needs.

But, on a wider scale, the four major reservoirs in Red Hills, Cholavaram, Poondi and Chembarambakkam are the major resource for water which contribute more than 60% of water that the city demands

Unfortunately, due to the mismanagement of water resources and due to the poor rain fall, the water content in these reservoirs reduced to 0.1% of its normal capacity in June 2019. This led to acute water shortage in the city.

On 19 June 2019, Chennai city officials declared that "Day Zero", or the day when almost no water is left, had been reached, as all the four main reservoirs supplying water to the city had ran dry.

DATA SET:

This project makes use of two data sets.

Dataset 1:

The data set details about the water availability in the four main reservoirs over the last 15 years

- Poondi
- Cholavaram
- Redhills
- Chembarambakkam

The data is available on a daily basis and the unit is million cubic feet.

Dataset 2:

The data set details about the rainfall in the above mentioned four main reservoirs over the last 15 years. This is also a data set that is collected on a daily basis and the unit is millimetres

Courtesy:

https://www.kaggle.com/sudalairajkumar/exploration-to-quench-chennai-s-thirst/data

DATA CLEANING PROCESS:

A data that is collected on a daily basis might be difficult to comprehend and to analyse. Thus the daily basis data is converted to a monthly data in which the average availability of water is entered against each month in case of the first data set and the total rainfall of each month is entered against each month in the case of second data set. This process projects the same data in such a way that analysis is made easy and the complexity of the data is reduced.

CONCEPTS USED:

1) ANOVA -Analysis of Variation
2) Time series forecasting
    a. Moving average
    b. Smoothening
    c. De-seasonalization

ANOVA:

Analysis of variance (ANOVA) is a collection of statistical models and their associated estimation procedures (such as the "variation" among and between groups) used to analyze the differences among group means in a sample.

ANOVA checks the impact of one or more factors by comparing the means of different samples.

The Null hypothesis in ANOVA is valid when all the sample means are equal, or they don't have any significant difference.

On the other hand, the alternate hypothesis is valid when at least one of the sample means is different from the rest of the sample means. In mathematical form, they can be represented as:

$$H_o: \mu_1 = \mu_2 = \cdots = \mu_L \qquad \textbf{Null hypothesis}$$

$$H_1: \mu_l \neq \mu_m \qquad \textbf{Alternate hypothesis}$$

ANOVA TABLE MODEL

Source of variation	Sums of squares Explanatory SS[11]	Sums of squares Computational SS[12]	Degrees of freedom DF	Mean square MS	F
Treatments	$\sum_{Treatments} I_j(m_j - m)^2$	$\sum_j \frac{(\sum_i y_{ij})^2}{I_j} - \frac{(\sum_j \sum_i y_{ij})^2}{I}$	$J-1$	$\frac{SS_{Treatment}}{DF_{Treatment}}$	$\frac{MS_{Treatment}}{MS_{Error}}$
Error	$\sum_{Treatments} (I_j - 1)s_j^2$	$\sum_j \sum_i y_{ij}^2 - \sum_j \frac{(\sum_i y_{ij})^2}{I_j}$	$I-J$	$\frac{SS_{Error}}{DF_{Error}}$	
Total	$\sum_{Observations} (y_{ij} - m)^2$	$\sum_j \sum_i y_{ij}^2 - \frac{(\sum_j \sum_i y_{ij})^2}{I}$	$I-1$		

Table 1

TIME SERIES ANALYSIS:

Time Series is a series of observations on a variable, recorded after successive equal time intervals. Here, the time period assumed is for quarterly data. The objectives to analyse time series are to study the past behaviour and to make forecasts for future. A time series consists of four components namely trend, cycle, seasonal and irregular.

1. *Trend* – It is the broad long-term tendency of either upward or downward movement in the average value of forecast.

2. *Cycle* – It is the upward or downward oscillation of uncertain duration due to the effect of seasonal cause. It may be either of long time or short time.

3. *Seasonal* – It is the special case of cyclic component of a time series where the duration does not vary but happen at a regular interval each year.

4. *Irregular* – It is the erratic movement in a time series with a short-term effect caused due to unforeseen circumstances that cause severe fluctuations

In this project, a multiplicative model of time series is assumed. This model assumes that as the data increase, so does the seasonal pattern. Most time series plots exhibit such a pattern. In this model, the trend and seasonal components are multiplied and then added to the error component.

SMOOTHENING USING MOVING AVERAGE TECHNIQUE:

Smoothing is a technique applied to time series to remove the fine-grained variation between time steps.

The hope of smoothing is to remove noise and better expose the trend of the underlying causal processes. Moving averages are a simple and common type of smoothing used in time series analysis and time series forecasting.

The formula for calculating simple moving average is:

$$SMA = \frac{A_1 + A_2 + \ldots + A_n}{n}$$

where:

A = average in period n

n = number of time periods

CENTERED MOVING AVERAGE:

When the period of time selected for calculating the simple moving average is even, then centered moving average is calculated in order to fit the entry perfectly. The centered moving average is calculating the averages of successive moving averages

DESEASONALIZATION:

A repeating pattern within each year is known as seasonal variation, although the term is applied more generally to repeating patterns within any fixed period.

The model of seasonality can be removed from the time series. This process is called Seasonal Adjustment or Deseasonalizing.

A time series where the seasonal component has been removed is called seasonal stationary. A time series with a clear seasonal component is referred to as non-stationary.

CHENNAI WATER SUPPLY:

As mentioned earlier, the forecast has been made on the basis of the availability of water in the four main reservoirs of the city. Figure 1 is a comparison graph between the availability of water in all the four reservoirs.

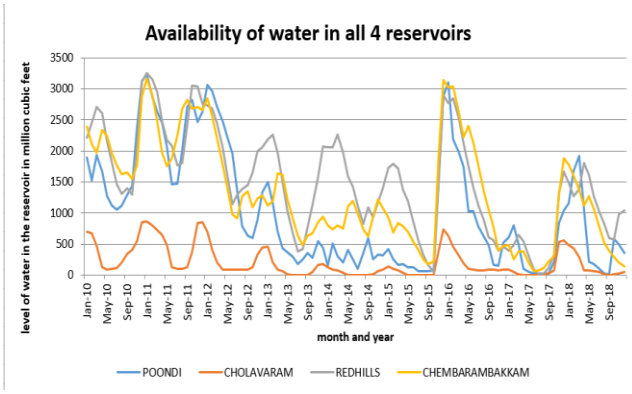

Figure 1

FORECAST FOR POONDI RESERVOIR:

Figure 2 represents the graph that explains the availability of water in Poondi reservoir in detail. The blue series represent the actual availability of water over the past 15 years. The orange series is the centered moving average of the poondi reservoir. This is used to smoothen the data and capture the trend of the availability of water roughly. The grey series represents the actual forecast for the availability of water in Poondi reservoir till the year 2020.

The forecast series, when observed keenly, it can be seen that the grey series captures values that are negative. This means that there would me literally no water left in Poondi reservoir if the current scenario continues to be the same.

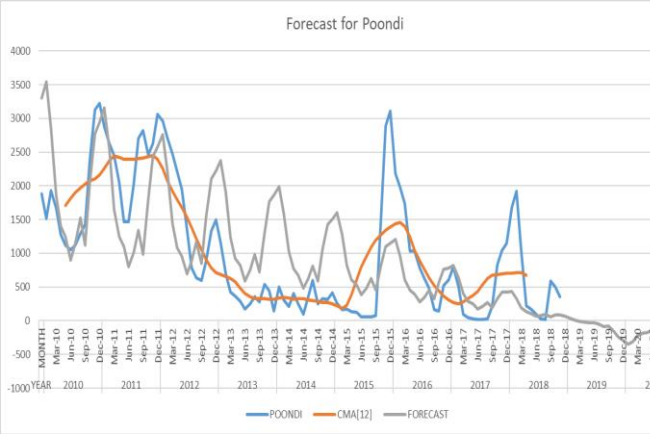

Figure 2

FORECAST FOR CHEMBARAMBAKKAM RESERVOIR:

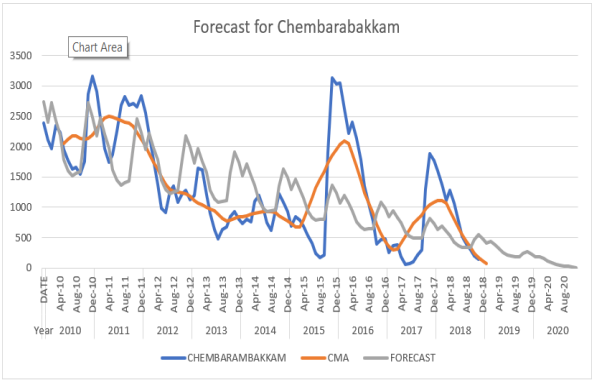

Figure 3

The Figure 3 represents the graph of water availability of Chembarambakkam reservoir. as mentioned earlier the blue series represents actual data, the orange series represents the centered moving average and the grey line is the forecast.

It can be observed that the water in Chembarambakkam reservoir is also depleting and it reaches almost zero in 2020.

FORECAST FOR CHOLAVARAM RESERVOIR:

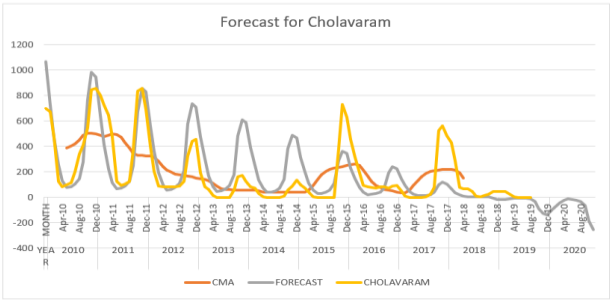

Figure 4

Figure 4 shows the graph of water availability of Cholavaram reservoir. The yellow series represents actual data, the orange series represents the centered moving average and the grey line represents the forecast. It can be observed that the reservoir has ran dry completely in 2019 itself.

FORECAST FOR REDHILLS RESERVOIR:

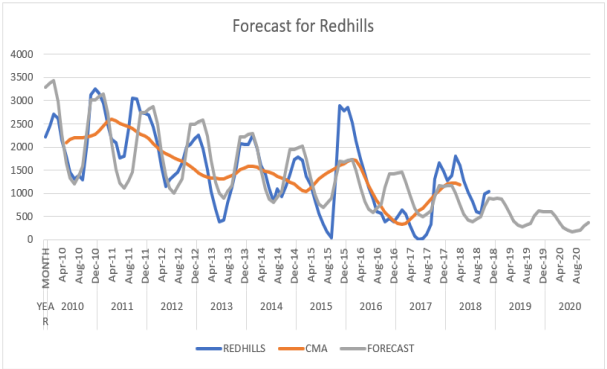

Figure 5

Figure 5 shows the graph of water availability of Redhills reservoir and its forecast. It is evident that the water availability in Redhills hasn't gone as worse as the other reservoirs. But still the level of water has

come down to a great extent and the forecast series shows the amount of water that would be available in 2020.

TOTAL AVAILABILITY FORECAST:

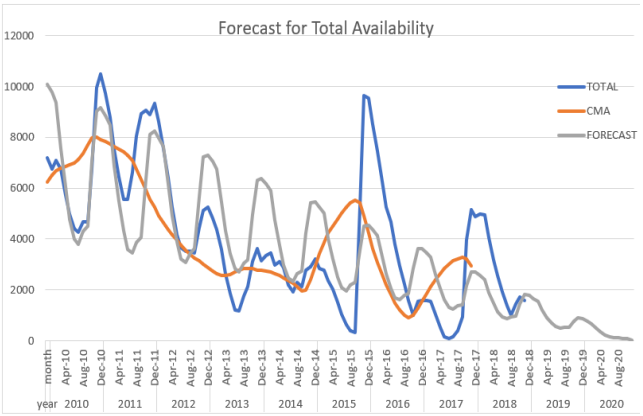

Figure 6

Figure 2, figure 3, figure 4 and figure 5 explained the availability of water in all the four reservoirs separately and also explains the forecast for 2020. Some of the reservoirs went totally dry in the mid of 2019 and some reservoirs had minimum amount of water left. This variation among the four graphs make it difficult to comprehend the data efficiently.

Figure 6 solves this problem. Here, the blue series represent the actual total amount of water present in all the four reservoirs together and the orange line as usual depicts the centered moving average which is used to capture the rough trend. The grey series represents the forecast values and this forecast graph is extended upto 2020.

From Figure 6, it can be clearly seen that if the scenario in Chennai city continues, then there would be literally no water left in all the four reservoirs as the forecast series almost touches zero in the end of 2020.

ROLE OF RAINFALL:

The level of water in the above mentioned 4 reservoirs is affected mainly by the amount of rainfall in the city. This led to the observation and analysis of the rain fall in the city.

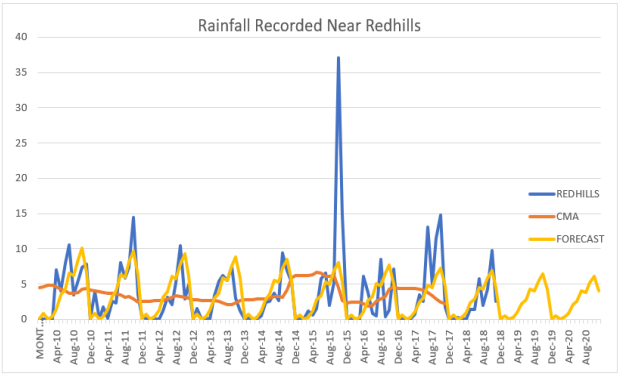

Figure 7

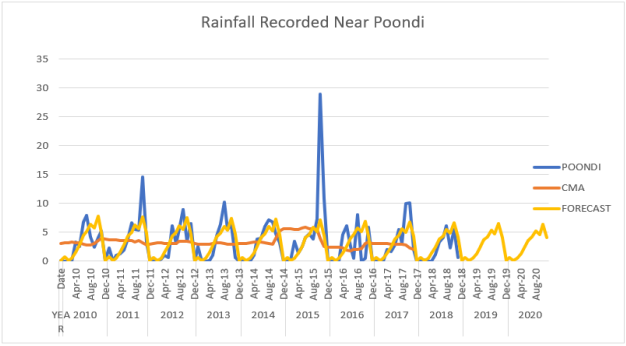

Figure 8

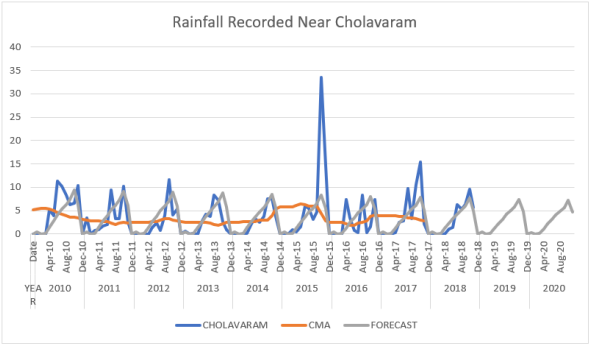

Figure 9

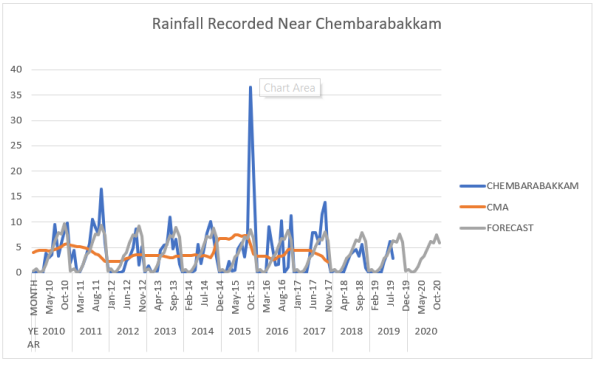

Figure 10

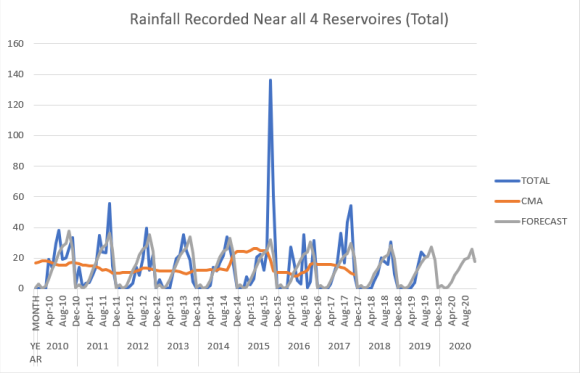

Figure 11

Figure 7, Figure 8, Figure 9, and Figure 10, shows the amount of rainfall recorded (in millimetres) in the areas of Redhills, Poondi, Cholavaram, and Chembarambakkam. It is evident that rainfall has increased tremendously during 2015. This was due to the floods that hit Chennai really hard during that period. If keenly observed, then it can be found that the levels of water in the above 4 reservoirs also would have increased drastically during that period. The forecast series of each graph captures the trend of the rainfall over seasons and predicts the rainfall in future.

Figure 11 shows the total rainfall recorded near all the four reservoirs in total as it is quite difficult to analyse and comprehend each reservoir separately. It can be observed from figure 11 that the rainfall follows a constant pattern over each year. The amount of rainfall increases during the period of august to October and starts sliding down during the end of November.

OVERALL INFERENCE:

Inspite of having a decent amount of rainfall in 2018 and a considerable amount of water available in all four reservoirs in 2018, the city still faced a major water crisis in the mid of 2019

This might be because of two main reasons.

1) Poor management of available water
2) The increase in demand for water in the city

The city of Chennai has grown to a great extent as compared to 10 years ago. But the availability of water remains the same. This is an important point to be noted by the authorities of the government and soon find an additional source for water supply.

Also, as for now, every drop water counts in Chennai city. Thus, efficient means to manage the available water wisely must be developed. the availability of water in these reservoirs, as mentioned before, is directly proportional to the amount of rainfall. Hence measures to increase rainfall can also serve efficiently. Some measures might include afforestation, balcony gardening and so on. Apart from these, rain water harvesting might also be of great help because this increases the ground water level which might serve as a helping hand when these reservoirs run dry.

Ideas like desalination of sea water and reverse osmosis of water can also be undertaken. Though the city already has 2 desalination plants already, the water supply is still not able to meet the demands completely.

CONCLUSION:

This is high time for the government to quickly find additional resources of water to the city. The residents of the city must also understand the seriousness of this crisis and act accordingly.

'Prevention is better than cure'

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