PREDICTION OF RAIN IN BIHAR, INDIA BASED ON HISTORICAL BIHAR'S RAIN DATA

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ABSTRACT

In this work the prediction of rain is based on average of three methods. In these methods, historical rain data of Bihar are selected for projection. These methods take into account the trends in rain pattern also.

Among the results are the effects of El Nino (meant to be excess rain) and La Nina (meant to be deficient rain) which have very significant effect on annual rainfall. The period of these combined effect found is 10.67 years. These results are shown in Fig. 7. The amplitude of these effects is 7.527 inches which means the total swing in rainfall is 15 inches approximately between good and bad rainfall years. The average rainfall of Bihar without trend is 48 inches approximately. So, about 31.25 % difference from the mean can be accounted for these two effects combined.

The predicted results are quite close to the actual rain data for the Year 2013. Based on this success, the forecast was made in December 2013 for the Year 2014. The predictions were verified on September 1, 2014. The predicted and the actual rainfall data for June, July, and August of 2014 are close as shown in Table 5.

The advantage of this approach is that it gives farmers far more time than they get presently when preliminary predictions are announced by Indian Meteorological Department in April for each monsoon.

As a matter of fact, the predictions can be made as early as in October of the previous year after collecting the rain data at the end of September.

KEYWORDS : Monsoon rain prediction **,** Annual rainfall**,** Rainfall frequency spectrum, El Nino and La Nina influence on rainfall, Drought and famine, Crop failure

1. RAIN AND AGRICULTURE

India is primarily dependent on its agricultural output which constitutes to its major fraction of GDP. The agriculture sector is highly dependent on rain which India gets from South –West monsoon rains. These rains occur during the months between June to September. Precipitation in form of rain, has a dramatic effect on agriculture.

Rising energy costs such as Diesel fuel used in pumps - have added to the country's foreign exchange needs and India is highly deficient in energy sources. This requires that the information about the amount of rain to be expected in coming season be known as accurately as possible.

Another factor which is playing havoc in the rainfall is the global warming which has introduced increased uncertainty in preparing for planting crops. This planting period is very sensitive and critical otherwise the farmers would have to wait for another year where these people do not have alternate means to earn their living. Such crop failures lead to large scale migrations from the villages to cities where people can earn some money to survive. This migration causes increased load on city's services and it increases slum areas in the cities.

The importance of planting period has been known to farmers since ages and are shown in Tables 1 and 2 [1-3].

2. RAIN PREDICTION IN INDIA

India's primary information about rain comes from India Meteorological Department (IMD) [4] . India has emphasized fair amount on research on rain predictions. It is known that monsoon is predicted either by statistical models based on analysis of historical data to determine the relationship of Indian Summer Monsoon Rainfall (ISMR) , to a variety of atmospheric and oceanic variables over different parts of the world prior to the summer monsoon season, or by dynamical models based on the laws of physics [5].

In April 2012, a paper on monsoon prediction by Delsole and Shukla [6] has made an important contribution in this matter. It was shown that predicting ISMR with couple atmosphere–ocean models initialized in the month of May is statistically significant and is much higher than empirical prediction from sea surface temperatures (SSTs) of May [5]. One can obtain other relevant references in [5].

Irrespective of methods used above, their validity over large tract of land area cannot be held as reliable because of their dependence merely on atmospheric and ocean parameters. Bihar happens to be a far distant land where the monsoon clouds reach after spreading over large land area. The convective conditions over the land areas are entirely different.

In view of the above argument, there is a need to have an alternate and reliable method of prediction for places like Bihar because the agriculturists are mainly of lower income group and un-reliability causes intense hardships.

3. HISTORICAL REASONS FOR PREPAREDNESS FOR DROUGHT IN BIHAR

Droughts and famines in Bihar have made major impacts in the history of India. Historical records exist as early as 4th century BC about famine in Bihar (Magadh) when large scale migrations of Jains took place to Karnataka under the leadership of Bhadrabahu [7,8].

One can also read about famine in Bengal- Bihar just when the British East India Company won over the Battle of Plassey in 1757. They built a granary at Patna called Golghar (Round House) as shown in Fig 1. It is a granary built by Captain John Garstin, in 1786. It can store vast quantity of grain. It was built after the devastating famine of 1770, which killed nearly 10 million people in regions of Bengal, Bihar and modern day Bangladesh [9].

Even recently, Nobel prize winner Amartya Sen has written about famine based on his personal experience [10] . As a boy, he witnessed the Bengal famine of 1943, in which three million people died. This was just before India obtained independence.

In 1981, Sen published – “Poverty and Famines: An Essay on Entitlement and Deprivation (1981)” , a book in which he argued that famine occurs not only from a lack of food, but from inequalities built into mechanisms for distributing food. Sen also argued that the Bengal famine was caused by an urban economic boom that raised food prices, thereby causing millions of rural workers to starve to death when their wages did not keep up.

India imported food-grain during 1966-67 Bihar Famine from U.S.A. under PL-480. In that time the grain production took a steep decline in all 17 out of 17 districts of Bihar and when the worst affected districts were in Central Bihar [11]. In this reference, there is a paragraph cited about Amartya Sen’s belief:

"Famines are easy to prevent if there is a serious effort to do so, and a democratic government, facing elections and criticisms from opposition parties and independent newspapers, cannot help but make such an effort. Not surprisingly, while India continued to have famines under British rule right up to independence …; they disappeared suddenly with the establishment of a multiparty democracy and a free press. "

The present situation in Bihar has striking similarity to the conditions described by Sen. People living in rural Bihar do not have jobs due to lack of industrialization caused by lawlessness, corruption, and lack of electricity, an essential element for industrial advancement and job creation. In addition, criminalization of politics which pervades India including in the Indian Parliament leaves those affected by drought without a place to seek help and this situation contrasts with Sen's paragraph written above where free press and frequent elections are given as factors in prevention of famine related deaths and sufferings. In actuality, the criminals turned politicians are immune from the effects of elections and the free press is also not able to prevent the criminals from getting elected [12] .

Fig. 2 shows the rain history in Bihar since 1959 where the trend has peaked in 1984; since then, it has a declining trend. Since 2002, this figure shows that the total rain in Bihar has been less than 40 inches in 6 different years. It shows low amounts of rain in 1966, 1972, 1992. and 2005 to name a few. Never has Bihar faced continued, more or less , low amount of rain as it has since 2002.

This year in 2013, the Bihar Government declared drought in 33 out of 38 districts which is similar to 1966. The question is : Given the history of famines and droughts in Bihar, what had the State and Central Governments done to prepare the people of Bihar for such an event and after the event? There does not appear to be much action to meaningfully help people to cope with continued drought conditions.

Was it possible for the governments and scientists of the country to publicly express warning? The IMD issues initial predictions around April, and then revises it in June approximately; this does not give adequate time to the farmers to prepare. The present work has been undertaken with this objective in mind.

4. RAIN DATA AND ANALYSIS

Fig. 3 shows a plot of yearly rain starting from 1981 to 2012. This shows a declining trend from year to year. This record has on an average of 48.342 inches of rain. One can clearly see that the plot has many ups and downs. However, low

amount of rain causes drought conditions such as in 2005, 2009, 2012 which are in this century and such lows have become quite frequent due to the lowering trend. It is not necessary that the entire country also experience similar lack of rain conditions. Therefore, it requires case by case analysis and fore-warn people against impending drought, if foreseen.

The second important factor which ought to be emphasized is shown in Tables 1 and 2 - is the timeliness of rain for planting crop. If the rain is delayed too much even then the hardship is going to be there. The farmers need fair bit of advance information to plan for seeds, and other necessities like finance to negotiate from the banks or other lenders. As is, India has much higher interest rates on loans compared to advanced countries which also have higher subsidies from their respective governments.

To get better insight into amount of rain over the years shown in Fig. 3, the same data was analyzed in the frequency domain using Fast Fourier Transforms (FFT), and the results are shown in Fig. 4 [13,14]. It shows frequency numbers which are quite significant are 3, 7, 10, 12 , and 16. It does point to the El Nino or its counterpart La Nina effect which occur every 10.67 years (frequency 3).

This rainfall data's statistical distribution was plotted and the result is shown in Fig. 5 which shows a normal distribution. This was further checked using chi squared test using a software called MATLAB.

Fig 6 shows a plot of the actual data and the results of FFT i.e. after obtaining Fourier Coefficients using FFT; the time dependent results were calculated using the Fourier series. It shows a very close match between the two.

Fig. 7 shows a plot of actual rainfall and frequencies 3, and 10 having period of 10.67 years and 3.2 years respectively . This figure very clearly shows good and bad duration are mainly affected by frequency 3 which has its up and down effects for many years

5. RAINFALL PREDICTION

It was not possible for the author to obtain Year 2013 rain data from IMD website while performing these calculations; they were made available after these calculations were performed.

Table 3 shows the results where data are arranged in different numbered columns. At first, the actual data are shown in millimeters as well as in inches. Next, the forecast data obtained by using the Moving Average Method are shown [13]. These calculations

were made for data between 2002 to 2012 (12 years) . These are shown in column 4. Similarly the results obtained by the FFT method are shown in column 5 which do not consider the declining trend. However, in column 6, the effect of declining trend is included.

Column 7 shows the average of the three methods with equal weightage recommended by the author. This is because there is uncertainty about the actual process which is not deterministic. This value turns out to be close to the actual data which was obtained after the calculations were performed. In all cases, these average values are closer to the actual rain values (column 3) than those predicted by IMD (column 9).

For the next year, Year 2014, the results are forecasted as shown in Table 4 which neither shows the actual rain data nor projections by IMD which are expected to come out in April of 2014. As explained in Fig. 7, we are going through La Nina effect which causes lack of rain condition over several years. In addition the total rainfall has lowering trend which makes matters worse taken together.

The actual and predicted rain figures between months of June, July, and August of 2014 are shown in Table 5 The predictions were verified on September 1, 2014. The predicted and the actual rainfall data for June, July, and August of 2014 are close as shown in Table 5. This verification took place on September 1, 2014.The actual and the predicted results are very close. This year, the rain deficiency is considerable as predicted.

By forecasting for the next year's rain values in December 2013, it gives sufficient information to farmers to plan accordingly.

6 CONCLUSIONS

In this work, at first a brief review of the drought and famine in Bihar was carried out. It was found that Bihar has had, on many occasions, severe drought conditions. As a result of this - granary was built in Patna, and it had resulted in mass migration of people from this area. Back in 1966, huge amount of wheat was imported from USA under PL-480 program.

The historical rain data showed that Bihar has had increasing trend in rainfall up to 1984 and then declining trend. The situation has worsened since the beginning of this century. Now, for several years, Bihar has had very low amount of rainfall.

At first a suitable model was searched for and it was found necessary to analyze the possible causes of the rainfall by looking at the frequency spectrum. The identified frequencies included the El Nino and La Nina effects amongst the others.

The rainfall predictions were made using Fourier series where both options – with and without trend and the resulting outcomes were noted.

The third approach was to use Moving Average Method of rainfall where linear regression model was thought to lead to better results.

Finally, the results of the three approaches were combined by computing average of the three methods.

The final prediction results matched quite well with the actual rain data of Year 2013 which was known only after the calculations were completed.

Based on this success for 2013, the prediction for the Year 2014 was made and found to be quite close as shown in Table 5. The predictions were verified on September 1, 2014.

7. REFERENCES

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TABLE 1 ADAPTING TO CHANGING WEATHER CYCLE: OBSERVATIONS [1]

NUMBER	NAKSHATRA	CALENDAR PERIOD	REMARKS
1	Ardra	22 June-5 July	Earlier start of sowing season (Rice)
2	Punarvasu	6 July-19 July	Now starting of sowing season
3	Pushya	20 July- 2 August	Now starting of sowing season
4	Aslesha	3 August-16 August	
5	Makha	17 August- 30 August	
6	Pubba	31 August-12 September	
7	Uttara	13 September-26 September	No Rain
8	Hasta	27 September-9 0ctober	No rain (Less Pulses Production)
Belief in Orissa	"Awat Adar Nahi Diyo Jat No Diyo hasta. Bina Khane Dona Gaye Pahuna aur Grihasta" (If there is no rain in Ardra (22 June–5 July) with the onset of the monsoon and No rain in Hasta (27 September–9 October) during the retreat, host And guest have to go without food		

TABLE 2 TIMELINESS OF RAIN IN MITHILA (BIHAR) , AND NEPAL TERAI (FOOTHILLS) [2,3]

NUMBER	SAYING IN MITHILA
1	“Aadi na bares aadra hasta na bares nidan Kahe Ghagh sun Bhaddari, bhaye kisan pishan.” IF there is no rain in the beginning of Ardra nakkshtra and if there is also no rain in the Hasta nakshatra then Ghagh says to Bhaddari listen there will be no rain and the farmer’s community will suffer a lot
2	“ Adra gele tinigel, san ,sathi aur kapas Hathiya gele sab gel, Aagin pachhilnas.” If there is no rain in the Ardra nakshtra then there will be no crop of jute, paddy and cotton. Likewise when in Hasta nakshtra if it does not rain then there will be no crop before and after.

TABLE 3 PREDICTED RESULTS FOR YEAR 2013

MONTH	ACTUAL (mm)	ACTUAL (Inches)	FORECAST- MOVING AVERAGE METHOD(Inches)	FORECAST- FFT WITH TREND (Inches)	FORECAST FFT NO TREND((inches)	RECOMMENDED AVERAGE OF THREE METHODS (Inches)	% AVERAGE OF THREE METHODS	FORECAST IMD (inches)	FORECAST IMD (mm)	% DIFFERENCE IMD
1	2	3	4	5	6	7	8	9	10	11
JUNE	176.7	7.0	6.4	7.3	7.5	7.1	-1.4	6.6	166.7	6.0
JULY	189.0	7.4	11.6	10.2	4.9	8.9	-16.5	14.0	356.6	-47.0
AUGUST	213.6	8.4	10.3	5.7	5.4	7.2	17.4	11.5	292.6	-27.0
SEPTEMBER	144.5	5.7	7.5	1.3	0.9	3.2	75.7	8.9	225.8	-36.0
JUNE TO SEPT	723.8	28.5	35.9	24.5	18.7	26.4	8.1	40.5	1027.6	-29.6

TABLE 4 PREDICTED RESULTS FOR YEAR 2014

MONTH	FORECAST- MOVING AVERAGE METHOD (Inches)	FORECAST- FFT WITH TREND (Inches)	FORECAST FFT NO TREND (Inches)	RECOMMENDED AVERAGE OF THREE METHODS (Inches)
1	2	3	4	5
JUNE	6.4	7.9	8.4	7.6
JULY	9.1	8.5	13.3	10.3
AUGUST	10.3	7.0	7.6	8.3
SEPT	7.4	2.9	3.0	4.5
JUNE TO SEPTEMBER	33.2	26.3	32.3	30.6

TABLE 5 : RAIN FIGURES FOR JUNE TO AUGUST 2014 (IN INCHES)

MONTH	PREDICTED	ACTUAL
JUNE	7.6	5.9
JULY	8.3	8.9
AUG	10.3	12.5
TOTAL	26.2	27.2

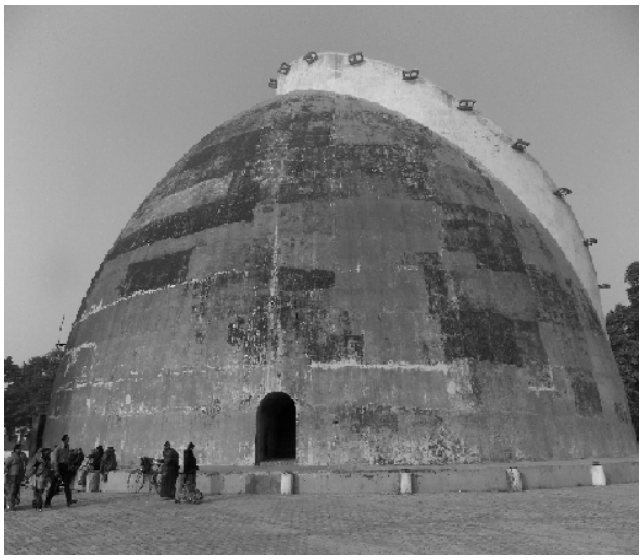

FIG. 1 GOLGHAR COMPLETED IN YEAR 1786 BY THE EAST INDIA COMPANY TO STORE GRAIN [COURTESY UDAY AND SANGEETA VARMA]

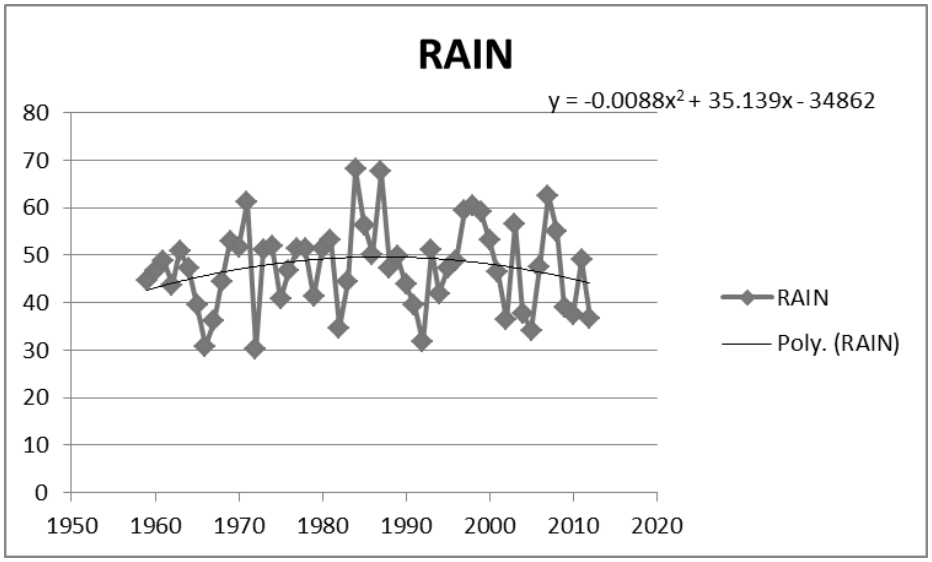

FIG. 2 TOTAL RAIN IN INCHES BETWEEN 1959 TO 2012

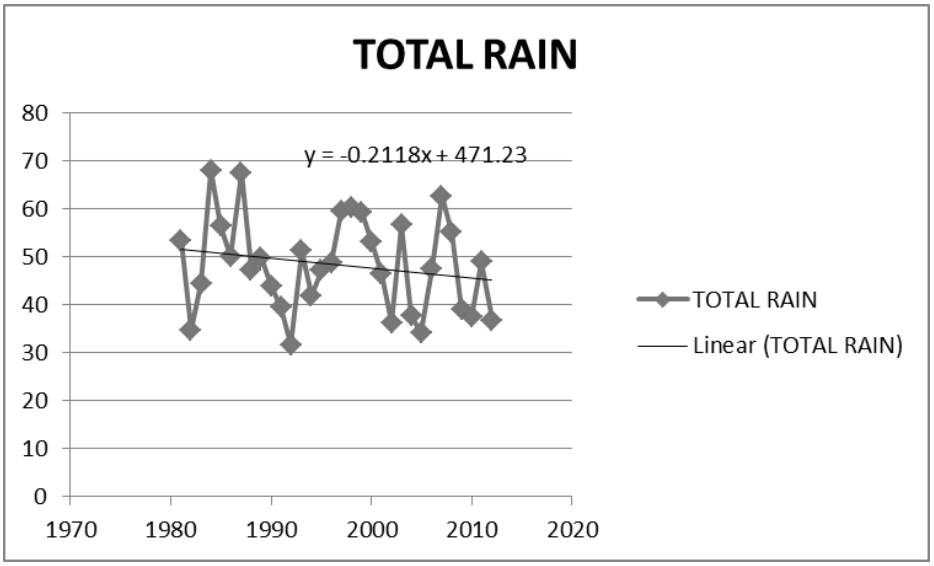

FIG. 3 TOTAL RAIN IN INCHES BETWEEN 1981 TO 2012

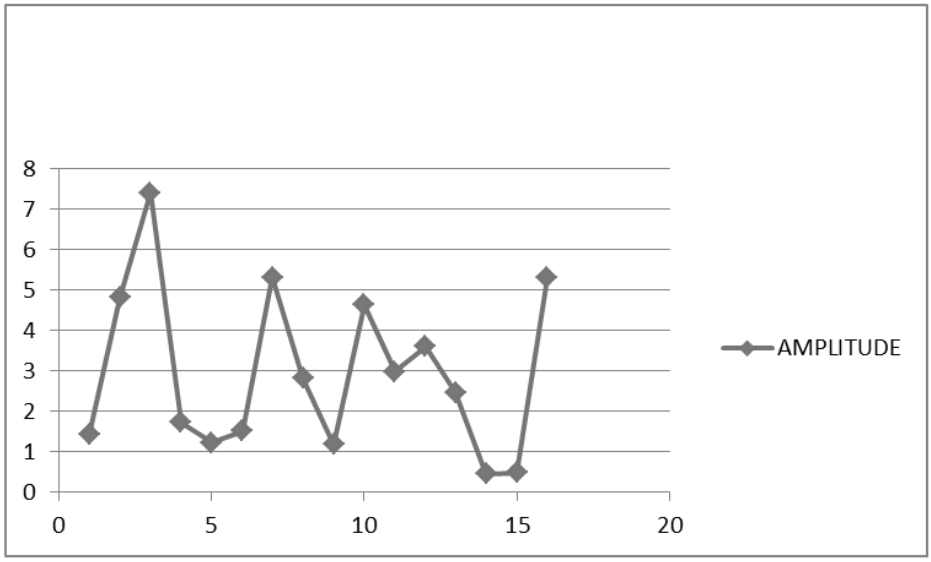

FIG. 4 AMPLITUDE VERSUS FREQUENCY

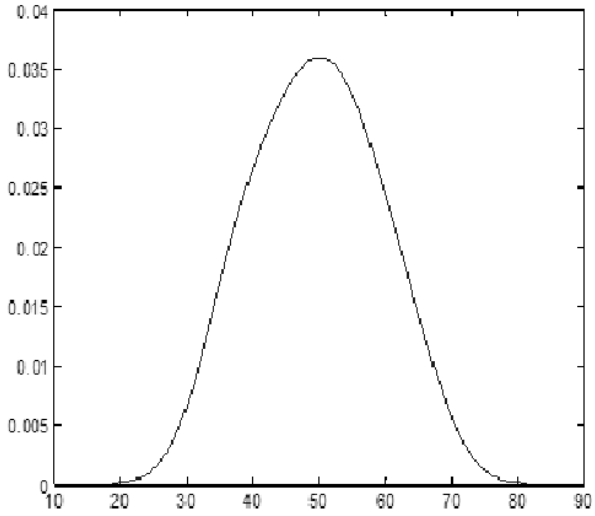

FIG. 5 NORMAL DISTRIBUTION OF YEARLY RAIN BETWEEN 1981 TO 2012

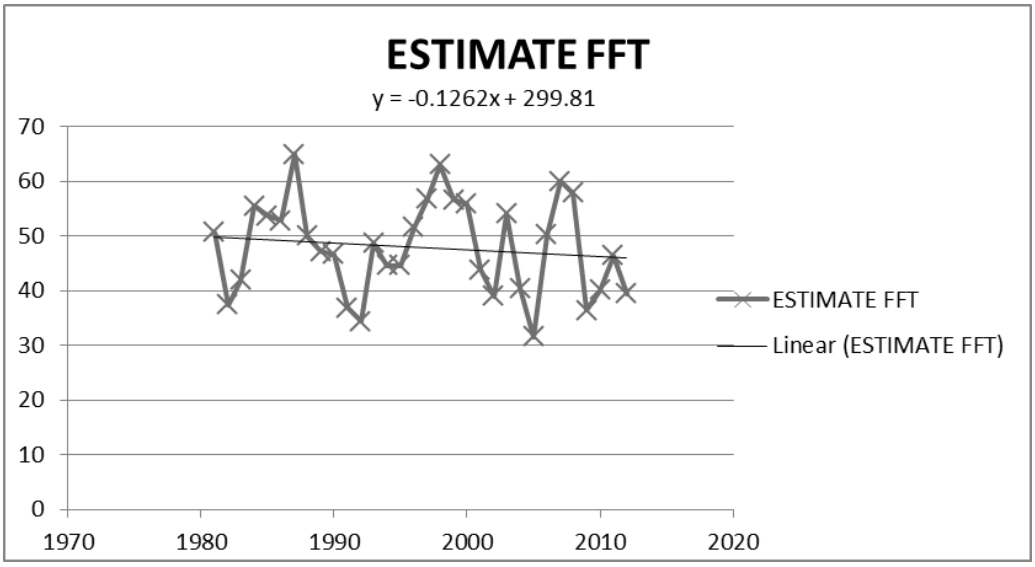

FIG. 6 MATCHING OF FFT MODELLED RESULTS WITH ACTUAL TOTAL RAIN IN INCHES BETWEEN 1981 TO 2012

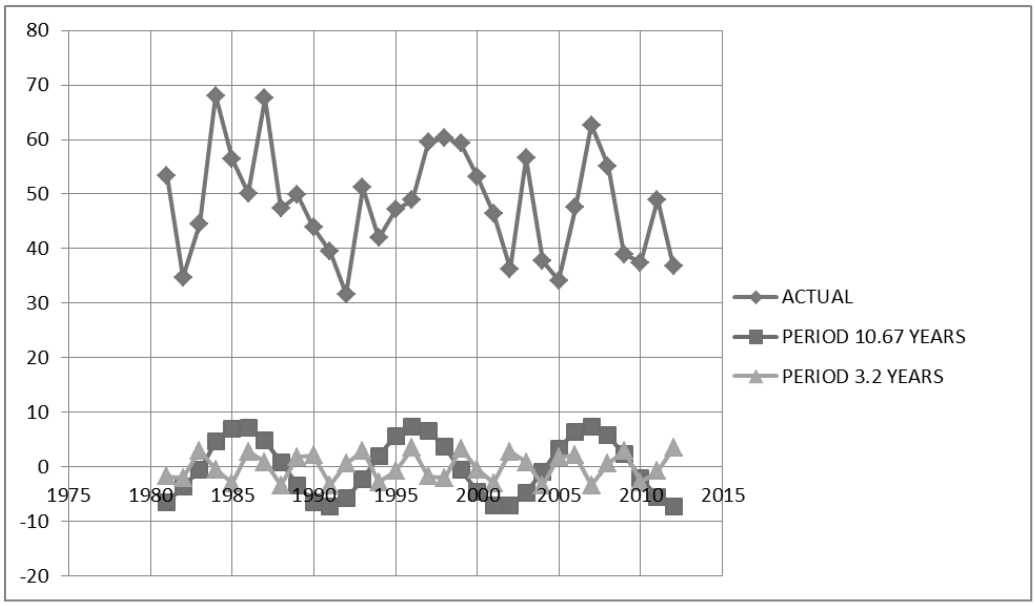

FIG. 7 PLOT OF ACTUAL RAIN , FREQUENCIES 3 AND 10 HAVING PERIODS OF 10.67 YEARS AND 3.2 YEARS RESPECTIVELY (INCHES) VERSUS YEAR