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STOCHASTIC MODELING FOR FORECASTING THE AGRO CLAIMATIC AREA KANCHEEPURAM

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ABSTRACT

By definition any mathematical form of a single and several variable functions can represent a distribution function if it can satisfy the four basic conditions namely non-negative, non-decreasing, and continuous to the right with total probability being one. This has given birth to many mathematical forms and the earlier attempts on rainfall analysis have screened many and the only two left are the Gamma distribution and the Weibull distribution of which the Weibull distribution is the generalized form of the Gamma distribution. In extremely arid regions the Gamma distribution is found to fit well. In the other regions Gamma Weibull log normal and exponential distributions were attempted and the right skewed is used. For each possible distribution the selection criteria was the value of chi-square minimum.

Methodology

The set back with this is that Harmonic Analysis cannot be used for forecasting. We have attempted the regression models namely

i. Linear model : $y_t = b_0 + b_1 t$
ii. Quadratic model : $y_t = b_0 + b_1 t + b_2 t^2$
iii. Growth model : $y_t = e^{b_0 + b_1 t}$
iv. Logarithmic model : $y_t = b_0 + b_1 \log t$

v. Cubic model : $y_t = b_0 + b_1 t + b_2 t^2 + b_3 t^3$
vi. S curve : $y_t = b_0 + b_1 t + b_2 t^2 + b_3 t^3$
vii. Exponential growth : $y_t = b_0 e^{b_1 t}$
viii. Inverse model : $y_t = b_0 + \frac{b_1}{t}$

ix. Logistic model : $y_t = \frac{1}{\left(\frac{1}{u} + b_0 b_1{}^t\right)}$

x. Power model : $y_t = b_0 t^{b_1}$

and none of the above gave any satisfactory solution and hence the stochastic modeling for forecasting is adopted. Since the use of distributions need data for verifying the predicted values with the actuals in the models used, we have used only fifty years data upto 2012 and the other four years data are kept for comparison to validate the forecasting power of the model selected.

To choose the appropriate probability distribution, the probability plots (P-P plots) are prepared for the fourteen stations based on the average rainfall for fifty years. The P-P plots indicated that the average rainfall lies close to the straight line representing the cumulative probability distribution of Gamma and Weibull distributions.

Though attempts were made to use the normal, lognormal, exponential, Gamma and Weibull distributions, the results were convincing only in the case of Gamma and Weibull distributions, since the other distributions did not fit well with the actual data. For each possible distribution the selection criteria was the chi-square minimum. Even in the selected distributions viz, Gamma and Weibull distributions, since the variability is high in the rainfall, natural logarithm of the rainfall was used as the dependent variable.

The mathematical form of the equations used are

1. Gamma distribution

$y = \frac{a^n}{\Gamma(n)} e^{-ax} x^{n-1}$ or $y = A\, e^{Bx}\, x^C$

which in natural logarithm becomes
lny = ln A + B x lne + C lnx
That is of the form lny = A + Bx + C lnx

The parameters were estimated through ordinary least squares. Here y is the natural logarithm of the rainfall value and x is the time parameter.

2. Weibull distribution

The general form of the distribution is

$$y = Ae^{-Bx^{\beta}} x^{\gamma-1} \quad \text{……….(i)}$$

which when β= 1 reduces to the Gamma distribution. Now taking natural logarithm (i) reduces to

$$\ln y = \ln A + B\, x^{\beta} \ln e + (\gamma - 1) \ln x$$

$$\text{That is } \ln y = A + B\, x^{\beta} + C \ln x$$

Since the actual value of β is not estimable through ordinary least square and β = 1 corresponds to Gamma distribution oscillations were made on β on both sides of one. That is β was oscillated from 0.999, 0.998 etc. downwards and 1.001, 1.002 etc. upwards until the chi-square between the observed and the estimated values came to a minimum. In the case of Gamma distribution this facility of oscillating the parameter is not possible and this might be the possible reason for the lower value of R^2 in Gamma distribution.

The final estimable form of the two distributions are

Gamma : $\log y = A + Bx + C \ln x$ where y = ln (rainfall in cm)
Weibull : $\log y = A + Bx^{\beta} + C \ln x$ where y = ln (rainfall in cm)
x in both the cases represent the time parameter. (in years)

Even after the transformation of the original rainfall values into natural logarithms the scatter diagram showed outliers due to the abnormal rainfalls in certain years and extremely low rainfall during very low rainfall periods. In order to accommodate these two, two dummies were used one for the surplus rainfall years (P_2) and another (P_1) for the very low rainfall periods. The introduction of these two parameters has helped in increasing the R^2 values for all the places. i.e. the explanatory power of the functions are increased to more than eight percent in many cases as revealed in the analysis.

Computational Analysis

The details of analysed results are presented in Table 1.1

Table 1.1

R^2 Value for Kancheepuram

Zone	Place	Months	R^2 – Value			
			Gamma distribution		Weibull distribution	
			Without dummy	With dummy	Without dummy	With dummy
I	Kancheepuram	June	0.027	0.765	0.031	0.765
		July	0.034	0.781	0.129	0.775
		October	0.03	0.729	0.03	0.729
		November	0.033	0.809	0.048	0.805

This enormous increase has helped to a larger extent in the assessment of the predicted value. So far, to our knowledge no study has used the dummy variable in the rainfall forecast. Since P_1 is the dummy for the very low rainfall periods its effect is one of lowering the values in these periods and hence the negative significance coefficients for P_1. The significance of the dummy coefficients suggests the validity of the use of the dummy. In a similar way P_2, the dummy for the high rainfall period has positive and significant coefficients indicating the significant addition in the surplus years. Thus the addition of the two dummies has helped in making close the predicted values even in the abnormal seasons. Apart from this in places wherein the dummy is not significant due to the insignificant increase or decrease in the slightly abnormal seasons the package itself has removed it, using step down procedure and given the solution without the dummies. These are indicated as blank spaces in the column for the dummy variables in the table wherein the results are presented. The parameter values for the Gamma distribution along with the dummy coefficient for all the fourteen rainfall stations are presented in Table 1.2. Comparisons were made between

the observed (O) and predicated values (E) and the $\chi^2 = \sum\left(\frac{(O-E)^2}{E}\right)$ for each and the total chi-square values are presented in Appendix III. The last column in each gives the $\chi^2 = \sum\left(\frac{(O-E)^2}{E}\right)$ for the particular observation. It is found that except Tuticorin for all the other places the values are very near to zero and the chi-square is very much below the significant level. The non-closeness for Tuticorin might be due to the unstability of the rainfall in this place in the rainy and non-rainy seasons.

Table 1.2

The parameter values for the Gamma distribution

Zone & Place		Months	A	B	C	P_1	P_2
I	Kancheepuram	June	1.317	-7.18E-04	6.39E-03	-0.437	0.268
		July	1.54	2.86E-03	-2.65E-02	-0.313	0.169
		October	1.615	-1.56E-04	1.37 E-02	-0.287	0.164
		November	1.611	-1.81E-03	3.57 E-02	-0.254	0.182

For convenience only the chi-square is tabulated and presented in Table 1.3

Table 1.3

The chi-square value for all the fourteen stations through both the distributions

Zone	Place	Month	Chi-square Value	
			Gamma distribution	Weibull distribution
I	Kancheepuram	June	0.4	0.39
		July	0.4	0.21
		October	0.29	0.29
		November	0.18	0.18

Since the Weibull distribution is the generalized form of the Gamma distribution, for the same set of observations the parameters of the Weibull distribution were estimated by assuming different values above and below one for the parameter β. For each value assigned for β in each one of the rainfall stations chi-square was estimated. The particular β for which the chi-square is minimum, is taken as the parameter value of β for each one of the stations. The oscillation of β is another degree of freedom got for making (O - E) to be very close and this has helped in increasing the R^2 values for each one of the functions along with the dummies as used in the Gamma distribution. The final parameter values for the Weibull distribution are presented in Table 1.4.

Table 1.4

The parameter values for the Weibull distribution

Zone & Place		Months	A	C	B	P_1	P_2	β
I	Kancheepuram	June	1.33	-3.73E-03	-5.28E-07	-0.438	0.268	2.1
		July	1.501	8.61E-03	2.19E-14	-0.313	0.172	7.3
		October	1.614	1.41E-02	-2.74E-04	-0.287	0.164	0.9
		November	1.644	8.87E-03	Excluded	-0.252	0.179	0.018

The observed value O, the calculated value E, and the chi-square value $\chi^2 = \sum\left(\frac{(O-E)^2}{E}\right)$ are presented in Appendix IV. The comparison of the results presented in the Appendix IV with that of the Gamma distribution presented in Appendix III, for each one of the fourteen stations shows that for the results through the Weibull distribution the chi-square values are lower than that for the Gamma distribution. Moreover as in the Gamma distribution the coefficients for dummies are also highly significant indicating its importance in making close the O and E values for all the stations. Thus the comparison reveals that the Weibull distribution can be considered as the form of distribution in forecasting the rainfall.

Since the primary objective is forecasting, to validate the models used, the actual data for 2012 to 2015 are compared with the forecasts drawn through the Gamma distribution and the Weibull distribution separately.

These values are presented in table 1.5

Table : 1.5

The actual data and the forecast from 2012 - 2015

Kancheepuram

Year	June			July			October			November		
	Observed	Weibull	Gamma	Observed	Weibull	Gamma	Observed	Weibull	Gamma	Observed	Weibull	Gamma
2004	34.20	41.20	40.03	142.80	140.66	129.28	441.80	490.96	493.55	183.20	145.80	132.70
2005	46.50	41.18	39.94	54.60	38.59	35.29	105.50	104.68	105.10	168.00	145.93	131.97
2006	16.00	11.01	10.81	387.30	403.19	325.16	103.70	104.73	105.15	166.20	146.05	131.24
2007	27.00	23.00	22.43	-	166.50	133.81	-	192.62	193.49	-	64.57	58.03

APPENDIX - III

The Chi-square value in the Gamma distribution

Kancheepuram

June			July			October			November		
O	E	$\left[\frac{(O-E)^2}{E}\right]$	O	E	$\left[\frac{(O-E)^2}{E}\right]$	O	E	$\left[\frac{(O-E)^2}{E}\right]$	O	E	$\left[\frac{(O-E)^2}{E}\right]$
1.32	1.32	0.00	1.57	1.54	0.00	1.67	1.62	0.00	1.81	1.79	0.00
1.54	1.59	0.00	1.7	1.70	0.00	1.58	1.62	0.00	1.35	1.38	0.00
1.23	1.32	0.01	1.45	1.52	0.00	1.53	1.63	0.01	1.73	1.65	0.01
1.53	1.59	0.00	1.72	1.68	0.00	1.59	1.63	0.00	1.56	1.65	0.01
1.39	1.32	0.00	1.22	1.20	0.00	1.67	1.64	0.00	1.67	1.66	0.00
1.44	1.32	0.01	1.48	1.51	0.00	1.54	1.64	0.01	1.52	1.41	0.01
1.03	0.89	0.02	1.51	1.51	0.00	1.48	1.35	0.01	1.21	1.41	0.03
1.31	1.33	0.00	1.54	1.51	0.00	1.79	1.81	0.00	1.65	1.67	0.00

1.29	1.33	0.00	1.74	1.51	0.04	1.75	1.64	0.01	1.36	1.42	0.00
1.35	1.33	0.00	1.44	1.51	0.00	1.66	1.65	0.00	1.47	1.42	0.00
1.5	1.32	0.02	1.38	1.51	0.01	1.69	1.65	0.00	1.28	1.42	0.01
1.56	1.59	0.00	1.33	1.36	0.00	1.58	1.65	0.00	1.75	1.68	0.00
1.12	1.32	0.03	1.21	1.20	0.00	1.8	1.81	0.00	1.78	1.68	0.01
1.29	1.32	0.00	1.4	1.51	0.01	1.64	1.65	0.00	1.74	1.68	0.00
1.57	1.59	0.00	1.49	1.68	0.02	1.52	1.36	0.02	1.89	1.86	0.00
1.38	1.32	0.00	1.69	1.51	0.02	1.71	1.65	0.00	1.47	1.43	0.00
1.58	1.59	0.00	1.41	1.68	0.05	1.74	1.65	0.01	1.49	1.43	0.00
1.26	1.32	0.00	1.53	1.52	0.00	1.7	1.65	0.00	1.73	1.68	0.00
0.93	0.89	0.00	1.63	1.52	0.01	1.61	1.65	0.00	1.83	1.86	0.00
1.29	1.32	0.00	1.56	1.52	0.00	0.98	1.37	0.11	1.7	1.68	0.00
1.42	1.32	0.01	1.57	1.52	0.00	1.72	1.65	0.00	1.81	1.86	0.00
1.36	1.32	0.00	1.52	1.52	0.00	1.42	1.37	0.00	1.64	1.68	0.00
1.54	1.59	0.00	1.49	1.69	0.02	1.56	1.65	0.01	1.65	1.68	0.00
1.25	1.32	0.00	1.45	1.52	0.00	1.89	1.82	0.00	1.77	1.68	0.01

1.37	1.32	0.00	1.6	1.53	0.00	1.62	1.66	0.00	1.88	1.86	0.00
1.31	1.32	0.00	1.56	1.53	0.00	1.78	1.82	0.00	1.57	1.68	0.01
1.31	1.32	0.00	1.53	1.53	0.00	1.74	1.66	0.01	1.58	1.68	0.01
1.35	1.32	0.00	1.54	1.53	0.00	1.65	1.66	0.00	1.51	1.43	0.01
1.63	1.59	0.00	1.43	1.70	0.04	1.55	1.66	0.01	1.52	1.43	0.01
1.58	1.59	0.00	1.65	1.71	0.00	1.73	1.66	0.00	1.79	1.68	0.01
1.38	1.32	0.00	1.59	1.54	0.00	1.82	1.82	0.00	1.86	1.86	0.00
1.55	1.58	0.00	1.56	1.71	0.01	1.87	1.82	0.00	1.86	1.86	0.00
1.33	1.32	0.00	1.52	1.54	0.00	1.55	1.66	0.01	1.67	1.68	0.00
1.26	1.32	0.00	1.56	1.54	0.00	1.65	1.66	0.00	1.64	1.68	0.00
1.18	1.32	0.02	1.63	1.55	0.00	1.18	1.37	0.03	1.63	1.67	0.00
1.19	1.31	0.01	1.56	1.55	0.00	1.73	1.66	0.00	1.26	1.42	0.02
1.39	1.31	0.01	1.52	1.55	0.00	1.48	1.37	0.01	1.68	1.67	0.00
1.34	1.31	0.00	1.63	1.55	0.00	1.79	1.82	0.00	1.39	1.42	0.00

1.28	1.31	0.00	1.7	1.55	0.01	1.22	1.37	0.02	1.52	1.42	0.01
1.31	1.31	0.00	1.31	1.24	0.00	1.52	1.37	0.02	1.85	1.85	0.00
1.26	1.31	0.00	1.33	1.25	0.01	1.44	1.37	0.00	1.54	1.67	0.01
1.25	1.31	0.00	1.57	1.56	0.00	1.39	1.37	0.00	1.61	1.67	0.00
1.33	1.31	0.00	1.7	1.56	0.01	1.38	1.37	0.00	1.71	1.67	0.00
1.41	1.31	0.01	1.63	1.57	0.00	1.42	1.37	0.00	1.56	1.67	0.01
1.23	1.31	0.01	0.92	1.26	0.09	1.65	1.66	0.00	1.47	1.41	0.00
0.54	0.87	0.12	1.16	1.26	0.01	1.35	1.37	0.00	1.73	1.66	0.00
1.01	0.87	0.02	1.28	1.26	0.00	1.78	1.82	0.00	1.89	1.85	0.00
1.5	1.31	0.03	1.62	1.57	0.00	1.72	1.66	0.00	1.82	1.84	0.00
1.8	1.58	0.03	1.34	1.43	0.01	1.62	1.66	0.00	1.7	1.66	0.00
1.22	1.31	0.01	1.29	1.27	0.00	1.65	1.66	0.00	1.69	1.66	0.00
		0.40			0.40			0.29			0.18

APPENDIX - IV
The Chi-square value in the Weibull distribution
(i) Zone : I Kancheepuram

June			July			October			November		
O	E	$\left[\frac{(O-E)^2}{E}\right]$	O	E	$\left[\frac{(O-E)^2}{E}\right]$	O	E	$\left[\frac{(O-E)^2}{E}\right]$	O	E	$\left[\frac{(O-E)^2}{E}\right]$
1.98	1.33	0.00	2.16	1.50	0.00	1.75	1.61	0.00	1.67	1.82	0.00
2.01	1.60	0.00	1.98	1.68	0.00	1.78	1.62	0.00	1.64	1.40	0.00
1.87	1.33	0.01	1.91	1.51	0.00	1.83	1.63	0.01	1.5	1.65	0.00
1.89	1.59	0.00	1.99	1.69	0.00	1.79	1.63	0.00	1.46	1.66	0.01
1.9	1.32	0.00	1.93	1.20	0.00	1.76	1.64	0.00	1.69	1.66	0.00
1.88	1.32	0.01	1.83	1.52	0.00	1.75	1.64	0.01	1.38	1.41	0.01
1.84	0.89	0.02	1.98	1.52	0.00	1.75	1.35	0.01	1.18	1.41	0.03
1.93	1.32	0.00	1.92	1.52	0.00	1.77	1.81	0.00	1.51	1.66	0.00
1.95	1.32	0.00	1.82	1.69	0.00	1.81	1.64	0.01	1.63	1.41	0.00
1.97	1.32	0.00	1.93	1.52	0.00	1.81	1.64	0.00	1.71	1.41	0.00
1.94	1.32	0.02	1.97	1.52	0.01	1.69	1.65	0.00	1.72	1.41	0.01
1.85	1.59	0.00	1.95	1.21	0.01	1.7	1.65	0.00	1.59	1.67	0.00

2.01	1.32	0.03	2.04	1.21	0.00	1.75	1.81	0.00	1.61	1.67	0.01
1.87	1.32	0.00	1.94	1.52	0.01	1.76	1.65	0.00	1.67	1.67	0.00
1.94	1.59	0.00	2.04	1.52	0.00	1.73	1.36	0.02	1.19	1.85	0.00
1.71	1.32	0.00	1.99	1.70	0.00	1.82	1.65	0.00	1.48	1.42	0.00
1.83	1.59	0.00	1.94	1.53	0.01	1.79	1.65	0.01	1.39	1.42	0.00
1.8	1.32	0.00	1.94	1.53	0.00	1.85	1.65	0.00	1.62	1.67	0.00
1.81	0.88	0.00	1.89	1.53	0.01	1.75	1.65	0.00	1.39	1.85	0.00
1.77	1.32	0.00	1.93	1.53	0.00	1.84	1.37	0.11	1.74	1.67	0.00
1.86	1.32	0.01	1.93	1.53	0.00	1.67	1.65	0.00	1.6	1.85	0.00
1.84	1.32	0.00	2.02	1.53	0.00	1.53	1.37	0.00	1.43	1.67	0.00

1.84	1.59	0.00	1.95	1.53	0.02	1.73	1.65	0.01	1.59	1.67	0.00
1.88	1.32	0.00	1.91	1.53	0.00	1.77	1.82	0.00	1.44	1.67	0.01
1.94	1.32	0.00	1.89	1.53	0.00	1.74	1.65	0.00	1.58	1.85	0.00
1.93	1.32	0.00	1.89	1.53	0.00	1.72	1.82	0.00	1.57	1.67	0.01
1.93	1.32	0.00	1.94	1.53	0.00	1.65	1.66	0.01	1.5	1.67	0.01
1.76	1.32	0.00	1.99	1.53	0.00	1.65	1.66	0.00	1.7	1.42	0.01
1.93	1.59	0.00	1.58	1.53	0.01	1.77	1.66	0.01	1.72	1.42	0.01
1.65	1.59	0.00	1.82	1.70	0.00	1.7	1.66	0.00	1.69	1.67	0.01
1.76	1.32	0.00	1.87	1.53	0.00	1.67	1.82	0.00	1.64	1.85	0.00
1.89	1.58	0.00	1.93	1.53	0.00	1.67	1.82	0.00	1.66	1.85	0.00
1.87	1.32	0.00	1.93	1.53	0.00	1.69	1.66	0.01	1.71	1.68	0.00
1.94	1.32	0.00	1.95	1.54	0.00	1.76	1.66	0.00	1.58	1.68	0.00
1.96	1.32	0.02	1.88	1.54	0.01	1.66	1.37	0.03	1.32	1.68	0.00
1.84	1.32	0.01	1.92	1.54	0.00	1.69	1.66	0.00	1.51	1.42	0.02
1.8	1.32	0.00	1.89	1.54	0.00	1.57	1.37	0.01	1.5	1.68	0.00
1.87	1.32	0.00	1.87	1.54	0.01	1.68	1.82	0.00	1.4	1.42	0.00
1.97	1.32	0.00	1.88	1.71	0.00	1.61	1.37	0.02	1.58	1.43	0.01
1.9	1.32	0.00	1.85	1.23	0.01	1.65	1.37	0.02	1.7	1.86	0.00
1.86	1.32	0.00	1.8	1.23	0.01	1.69	1.37	0.00	1.57	1.68	0.01
1.82	1.32	0.00	1.93	1.55	0.00	1.7	1.37	0.00	1.09	1.68	0.00

1.89	1.31	0.00	1.96	1.72	0.00	1.78	1.37	0.00	1.52	1.68	0.00
1.85	1.31	0.01	1.89	1.56	0.00	1.74	1.37	0.00	1.68	1.68	0.01
1.94	0.88	0.01	1.95	1.25	0.08	1.68	1.66	0.00	1.17	1.43	0.00
1.95	0.88	0.13	1.98	1.25	0.01	1.73	1.37	0.00	1.66	1.68	0.00
1.86	1.31	0.02	1.94	1.26	0.00	1.84	1.82	0.00	1.63	1.86	0.00
1.96	1.31	0.03	1.98	1.58	0.00	1.81	1.66	0.00	1.68	1.86	0.00
1.84	1.58	0.03	1.93	1.27	0.00	1.65	1.66	0.00	1.68	1.68	0.00
1.87	1.31	0.01	1.94	1.28	0.00	1.5	1.66	0.00	1.19	1.68	0.00
		0.39			0.21			0.29			0.18

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