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TREND ANALYSIS AND PREDICTION OF RAINFALL USING GENETIC ALGORITHM

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ABSTRACT

In India, rural areas are economically relying on agriculture for their livelihood. Rainfall prediction is essential because rain is the primary source of irrigation for agriculture in rural areas. In this present Study, SPM (Simple Prediction Model) is developed using the Genetic Algorithm approach and historical rainfall data of 10 years. Firstly, the model analyses the monsoon rainfall trend and then it predicts the daily rainfall. Root Mean Square Error (RMSE) is used to measure the accuracy of the model. The trend analysis and rainfall prediction can be very useful to the farmers to takes various agricultural decisions.

Keywords: *Genetic Algorithm, Matlab Programming, Prediction, Rainfall, SPM*

1. INTRODUCTION

1.1. Agriculture and Rainfall: In India, two-third of the population is involved in the agricultural sector. Most of the peoples that reside in rural areas are the farmers and economically dependent on agriculture for their livelihood. In India, a state like Gujarat has varying topographic distinctive features of agro-climatic zones with 1500mm and more rainfall in south Gujarat (Heavy rain area), 1000 to 1500mm rainfall in middle Gujarat and 625mm to 875mm rainfall in north Gujarat [11]. In Gujarat, rainfall prediction is crucial because rain is the primary source of irrigation for agriculture. It helps farmer to make a crucial agricultural decision. Prediction uses different approaches, like statistical methods and stochastic methods. These methods showed the best promising results for the linear data, but for the non-linear rainfall data, these methods do not give an accurate and best promising result [3].

1.2. Prediction Technique: Data mining can be considered as a useful technique for identifying the pattern hidden in the non-linear data. So using the data mining technique for prediction of rainfall can probably give us accurate results. It is a useful technique for the prediction of non-linear data. Different data mining techniques and algorithms like Decision tree (CART), clustering (k-mean clustering), Artificial Neural Network Fuzzy System, Genetic Algorithm and others are used for forecasting using the meteorological data.

1.2.1 Genetic algorithm (GA): Genetic algorithm is the search heuristic optimization algorithms based on the natural evolution principles. GA is best suited for the non-linear problem. Depending on Charles Darwin's theory of evolution for the fittest to survival and the ideas of selection, mutation and crossover. GA targets the identification of an optimal solution for an optimization problem over different generations. [2].

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Sets of Genetic Algorithm

Step 1 Generate the random initial population of a known solution set.

Step 2 The Fitness of each member of the population is calculated.

Step 3 if the member is sufficiently good or exit condition is reached, the algorithm will stop and obtain the required result.

Step 4 Otherwise, develops a new population for the next generation using the following genetic operation.

Step a. Selection – Two members are selected from the population depending upon their fitness values.

Step b. Crossover– Crossover Probability applies to the selected parents to form new children.

Step c. Mutation – Mutate the new children with the mutation probability.

Step 5 Overrides the old population with the newly created population and goto step 3 [4].

1.3. Rainfall Trend: Trend analysis uses historical results to predict future outcomes. "The increasing or decreasing trend was tested based on normalized test statistics (Z) value. When Z is positive, the trend is increasing and when Z is negative, it is said to be decreasing. The trend's slope gives the direction of change" [6]. Different methods/tests like regression-tests, Sen's Slope Estimator Test, Kendall rank correlation test, Spearman rank correlation test and Mann–Kendall Test analyze the trend of weather parameters like temperature, rainfall, and others.

1.3.1 Regression analysis is a parametric technique for analyzing and modeling relationship between a dependent variable and a set of independent variables. [17] It was performed on the observed time-series data of rainfall and then the linear trend was tested on relationship between the time and variable. A linear equation, $y = mx + c$, defined by c (the intercept) and trend m (the slope), which represents the rate of increase or decrease of the variable, can be fitted by regression [14].

1.4. Programming Tools: Programming tools are used to build the model. Different types of programming tools like Julia, GNU Octave, Python with scientific tools, Matlab, Scilab, R-software and many more are easily available to develop and code the prediction model. In this study, Matlab is used to build the model.

1.4.1 MATLAB (matrix laboratory) is a high-level programming language integrated with visualization, numerical computation and programming environment developed by Math Works. It supports different functionality like matrix manipulations, Algorithms implementation and data analyzing. Users can create their own interfaces program, applications and model using programming languages like C, C++, Java, and FORTRAN [15].

1.5. Model evaluation metrics: Once the model is build, it is necessary to examine the quality of the model. Different model evaluation metrics are used to find the difference between actual and predicted values of the model. MAE (Mean Absolute Error), MSE (Mean Square Error), RMSE (Root Mean Square Error) and others are some examples of model evaluation metrics.

1.5.1 Root Mean Square Error (RMSE): Root Mean Square Error is a measure of the differences between the real observed value and the predicted value of the thing which is being modeled [10]. The value of RMSE is always non-negative and 0 values indicate that data is the perfect fit. RMSE is used to find the accuracy of the model.

1. LITERATURE REVIEW

Lin-Chih Chen and his team presented a page clipping synthesis (PCS) search method to extract relevant paragraphs from web search results. To create a set of best-of-run page clippings in a specific amount of time, dynamically terminated GA is applied by the PCS search method. The benefit of page clippings is to save the user's time by providing the most exciting information to the users. A

cost-effective solution is achieved by dynamically terminated GA as compared to conventional GA. [5].

L. Haldurai, T. Madhubala and R. Rajalakshmi need some measure to split the best solution from the worst to obtain the best solutions. Subjective or objective (statistical model or simulation) measure is required to choose the best solution. Moreover, GA is used the fitness function to determine the best solution for a given problem. This research shows how various techniques and methods merged with GA to get the optimal solution and increase the computation time in various GA applications [4].

Mohammad Anisur Rahman and his team used 40 years of rainfall data of 31 rain gauge stations from Bangladesh intending to examine variability and trend of the rainfall. The linear regression model understands the annual trend and prediction of annual rainfall and various categories seasons like winter, monsoon, and pre &post-monsoon. The result obtained from the study indicates that the rainfall is stable in monsoon and post-monsoon, while winter, pre-monsoon and annual rainfall are decreased precipitation in the future. When compared with the observed data, the best-fitted prediction model gives a better result of rainfall prediction. Thus, it is best to use a model for future rainfall prediction [7].

Adil M. Bagirov, Arshad Mahmood and Andrew Barton combined the regression techniques and clustering to developed Cluster wise linear regression technique for the monthly rainfall prediction in Victoria. The proposed technique used the data collected from eight weather stations in Victoria, Australia, from 1889-2014. CLR technique evaluates the prediction performance using different measures (RMSE, MAE, MASE, COE) of forecast accuracy by comparing actual and predicted values. In this study, the result demonstrates that the current technique outperforms other prediction techniques like SVM, ANN and MLR in most locations [1].

Mohammad Reza Bonyadi and his team propose a new approach to schedule the disk request by integrating a genetic algorithm. They have used a simple coding technique that applies genetic algorithm procedures like crossover, mutation and calculating the fitness value using a penalty function. The proposed method is compared with the different methods used in related work by implementing several different problems. Experimental results obtained to state that the proposed method outperformed other methods used in related work to have fewer missed tasks and average seeks. However, when compared with the C-scan algorithm, it has lower average seeks [8].

3. PROPOSED METHODOLOGY

Darwin's theory of evolution and natural selection, i.e., the Genetic algorithm has been used to develop the proposed SPM (Simple Prediction Model). The model's objective is to analyze the monsoon rainfall trend and then predict the daily rainfall by using historical data. The RMSE values will check the performance and accuracy of the model. The proposed SPM approach collects raw weather data, pre-processes the raw data, finds the trends of the monsoon rainfall and processes the Genetic algorithm to predict the daily rainfall.

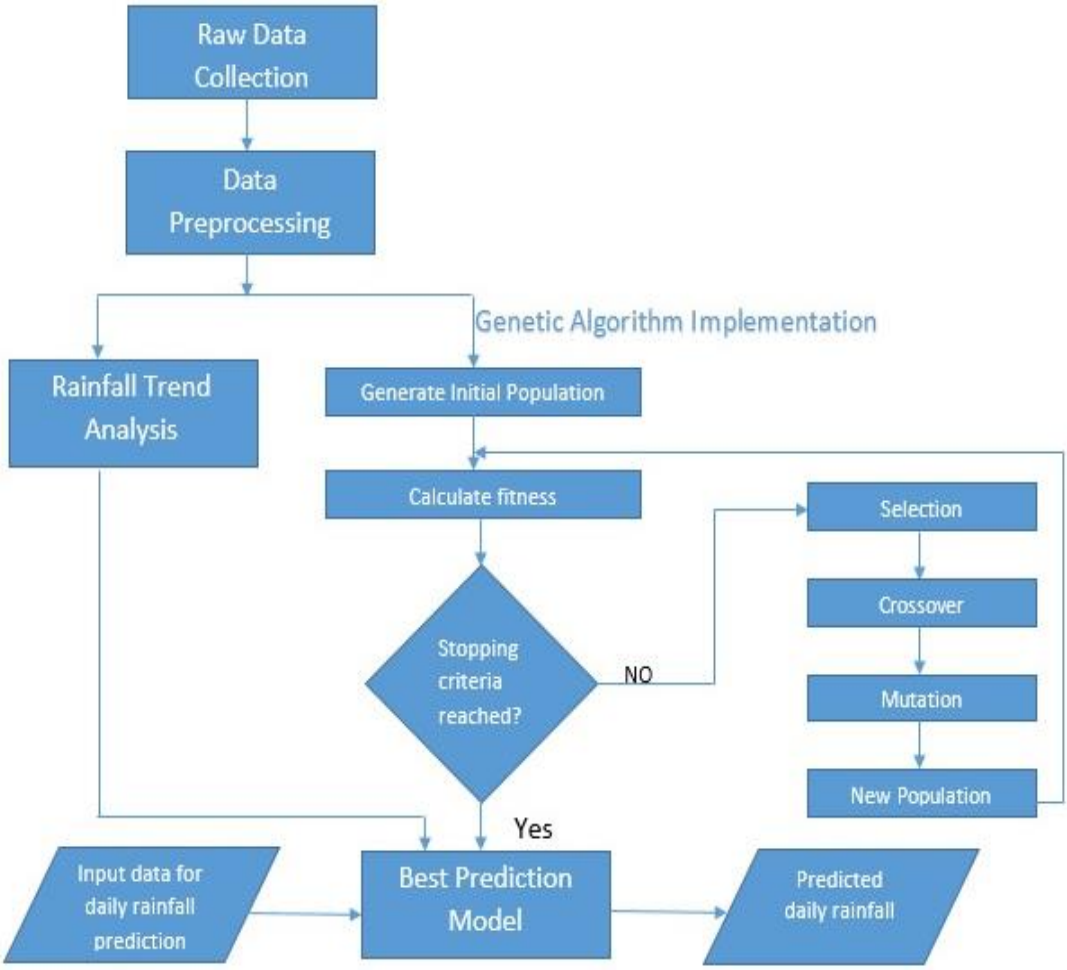

Fig. 1 SPM

3.1 **Raw Data Collection:** The study used raw data (3652 records) of 10 years, collected from the Department of Agri-meteorological, Navsari Agricultural University, Navsari. The model used 70% data (2555 records) from 2009-2015 and 30% data (1096 records) from 2016-2018 for training and testing, respectively. Table 1 describes the six input attributes used by SPM. Rainfall Type is the output attribute categorized into the class [16] given in Table 2.

Table 1. Input Attributes of SPM Data

Sr.no	Attributes	Type	Description	Unit
1.	Tmax	Numerical	Maximum Temperature	°C
2.	TMin	Numerical	Minimum Temperature	°C
3.	RH	Numerical	Relative Humidity	%
4.	WS	Numerical	Wind speed	Km/h
5.	Rf	Numerical	Rainfall	Mm

Table 2. Class of Output Attributes

Sr. no.	Class Name	Rainfall Range (in mm)
1.	No Rain	0
2.	Light Rain	0.1 to 7.5
3.	Moderate Rain	7.6 to 64.4
4.	Heavy Rain	64.5 to 244.4
5.	Extremely Heavy Rain	Above 244.4

3.2 Pre-processing Data: In the pre-processing stage, raw data is cleaned and normalized. Data cleaning operation replaced the missing/blank value by the mean of the given attributes. Further, the value of the attribute is set and partitions the data into bins through the binning process.

	A	B	C	D	E	F	G	H
1	Days	DATE	Tmax	Tmin	RH %		Ws(km/hrs)	Rf (mm)
233	231	August 19, 2009	33.0	25.5	82	61	4.3	0.0
234	232	August 20, 2009	33.5	27.0	87	63	5.3	0.0
235	233	August 21, 2009	34.5	26.7	83	70	6.6	0.0
236	234	August 22, 2009	32.0	25.5	89	61	7.7	8.0
237	235	August 23, 2009	32.5	26.5	84	67	7.1	0.3
238	236	August 24, 2009	32.5	26.0	89	61	6.6	0.0
239	237	August 25, 2009	33.5	27.0	85	61	8.2	0.0
240	238	August 26, 2009	34.0	22.5	95	72	9.3	4.7
241	239	August 27, 2009	31.0	27.2	82	92	8.7	0.0
242	240	August 28, 2009	27.5	25.5	87	96	4.6	12.0
243	241	August 29, 2009	26.0	24.0	95	95	3.7	53.0
244	242	August 30, 2009	28.0	24.5	97	89	5.2	52.0
245	243	August 31, 2009	27.5	24.0	88	76	7.9	39.0
246	244	September 1, 2009	30.3	25.0	93	74	8.2	9.0
247	245	September 2, 2009	30.0	26.5	92	85	4.9	0.0
248	246	September 3, 2009	29.2	23.0	95	84	7.6	11.0
249	247	September 4, 2009	27.0	23.0	95	82	4.1	58.0
250	248	September 5, 2009	29.5	26.5	87	76	8.8	11.0
251	249	September 6, 2009	31.5	26.5	89	83	8.8	0.0
252	250	September 7, 2009	30.5	24.0	97	89	6.9	135.0
253	251	September 8, 2009	28.2	25.0	94	72	5.9	16.0
254	252	September 9, 2009	31.5	27.0	89	72	5.8	0.0
255	253	September 10, 2009	31.2	26.5	89	76	8.6	0.0

Fig. 2 Dataset before pre-processing

After that, clean data are normalized and scaled between the values [0-1], which minimize the errors [12]. The normalization equation is as follow;

$$Xnorm = \frac{Xt - Xmin}{Xmax - Xmin}$$

Here, Xt is actual data, Xmax and Xmin is the maximum and minimum value of x variable, respectively. Xnorm is a normalized output data [4].

Now the obtained pre-processed data shown in Fig. 3 is ready for building the model.

A	B	H	I	J	K	L	M
Days	DATE	Tmax	Tmin	RH%	Ws(km/hrs)	Rf (mm)	Rainfall Ty
175	June 24, 2009	0.75	0.90	0.77	0.64	0.00	No Rain
176	June 25, 2009	0.75	0.91	0.76	0.72	0.00	No Rain
177	June 26, 2009	0.76	0.88	0.85	0.69	0.02	Light Rain
178	June 27, 2009	0.75	0.86	0.94	0.63	0.12	Moderate Rain
179	June 28, 2009	0.65	0.90	0.89	0.48	0.01	Light Rain
180	June 29, 2009	0.65	0.88	0.90	0.49	0.06	Moderate Rain
181	June 30, 2009	0.70	0.86	0.84	0.53	0.06	Moderate Rain
182	July 1, 2009	0.74	0.91	0.77	0.61	0.00	No Rain
183	July 2, 2009	0.75	0.88	0.80	0.66	0.09	Moderate Rain
184	July 3, 2009	0.76	0.87	0.94	0.63	0.10	Moderate Rain
185	July 4, 2009	0.65	0.87	0.90	0.49	0.07	Moderate Rain
186	July 5, 2009	0.71	0.90	0.84	0.52	0.00	No Rain
187	July 6, 2009	0.75	0.76	0.86	0.44	0.20	Moderate Rain
188	July 7, 2009	0.74	0.91	0.89	0.54	0.00	No Rain
189	July 8, 2009	0.74	0.80	0.91	0.65	0.28	Moderate Rain
190	July 9, 2009	0.67	0.90	0.93	0.51	0.06	Moderate Rain
191	July 10, 2009	0.67	0.86	1.00	0.55	0.21	Moderate Rain
192	July 11, 2009	0.67	0.88	0.88	0.45	0.06	Moderate Rain
193	July 12, 2009	0.71	0.90	0.86	0.71	0.03	Light Rain
194	July 13, 2009	0.68	0.86	0.87	0.78	0.33	Moderate Rain
195	July 14, 2009	0.69	0.89	0.89	0.55	0.07	Moderate Rain

Fig. 3 Dataset after pre-processing

3.3 **Analyzing rainfall trend:** The monsoon rainfall trend is analyzed from past historical data, shows the increase and decrease of rainfall for particular months. In this study, the Regression Analysis method is used to analyze the trend. The Regression analysis was performed for the annual rainfall time series data as well as the monsoon rainfall time series data for the month of June, July, August and September [14].

3.4 **Building Predictive Model:** MATLAB is used to develop SPM. Different inbuilt functions and methods of the Genetic algorithm are available in Matlab. Different parameters are determined to build the model. These parameters include the population size, selection technique, crossover, mutation probabilities and others. [9]. The model used fitness functions that evaluate the error to find the best and accurate prediction. The error is defined as the difference between actual and predicted output values. Performance evaluators, namely RMSE, are used to judge the performance of this model. The GA parameters which are applied to this model are presented in below Table 3.

Table 3. Genetic Algorithm parameters setting

Population Size	100
Fitness Scaling Method	Rank
Selection Mechanism	Roulette Wheel Selection
Crossover Probability Rate	0.85
Mutation Probability Rate	0.05
Number of Generation	100
Lower & Upper bound	[0 1]
Stopping Criteria	Fitness limit reached or Maximum Generation completed

4. EXPERIMENTAL RESULT AND DISCUSSION

In SPM, firstly, the rainfall trend was analyzed and discussed. The time-series dataset of Navsari Station for ten years, from 2009 to 2018 was used to find the annual and monsoon season (June, July, August and September) rainfall trend. In fig. 4 the value of slope for annual rainfall is -42.761 which indicate there was decreasing trend for annual rainfall.

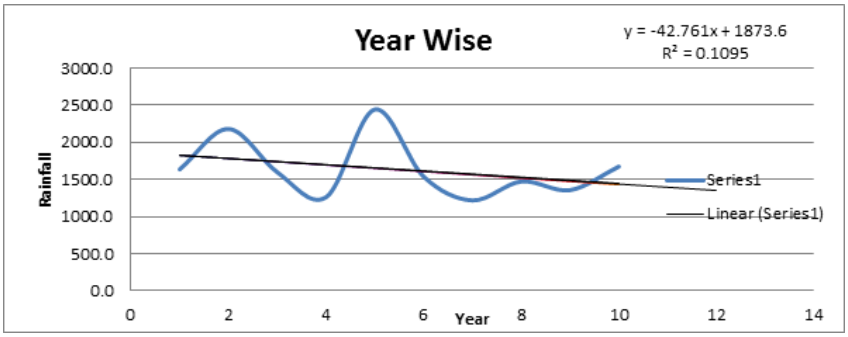

Fig. 4 The trend of Annual rainfall from 2009 to 2018

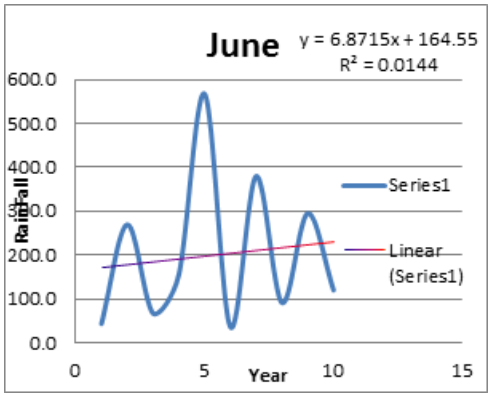

Fig. 5 The trend of June month rainfall from 2009 to 2018

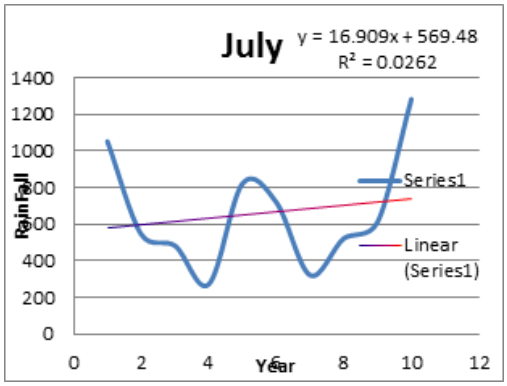

Fig. 6 The trend of July month rainfall from 2009 to 2018

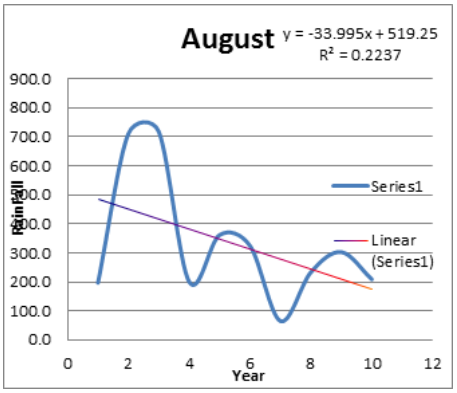

Fig. 7 The trend of August month rainfall from 2009 to 20181

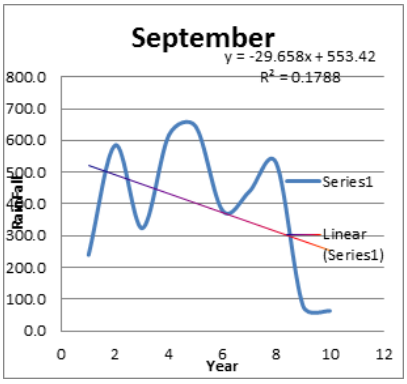

Fig. 8 The trend of September month rainfall from 2009 to 2018

The above fig. 5, 6, 7 and 8 showed that in June& July, the rainfall trend was increased and in August & September, the rainfall trend was decreased per year from 2009 to 2018. Once the trend was analyzed, SPM predicts the daily rainfall by evaluating each record using a Genetic algorithm. RMSE value of both the training and testing dataset measured the performance and accuracy of SPM.

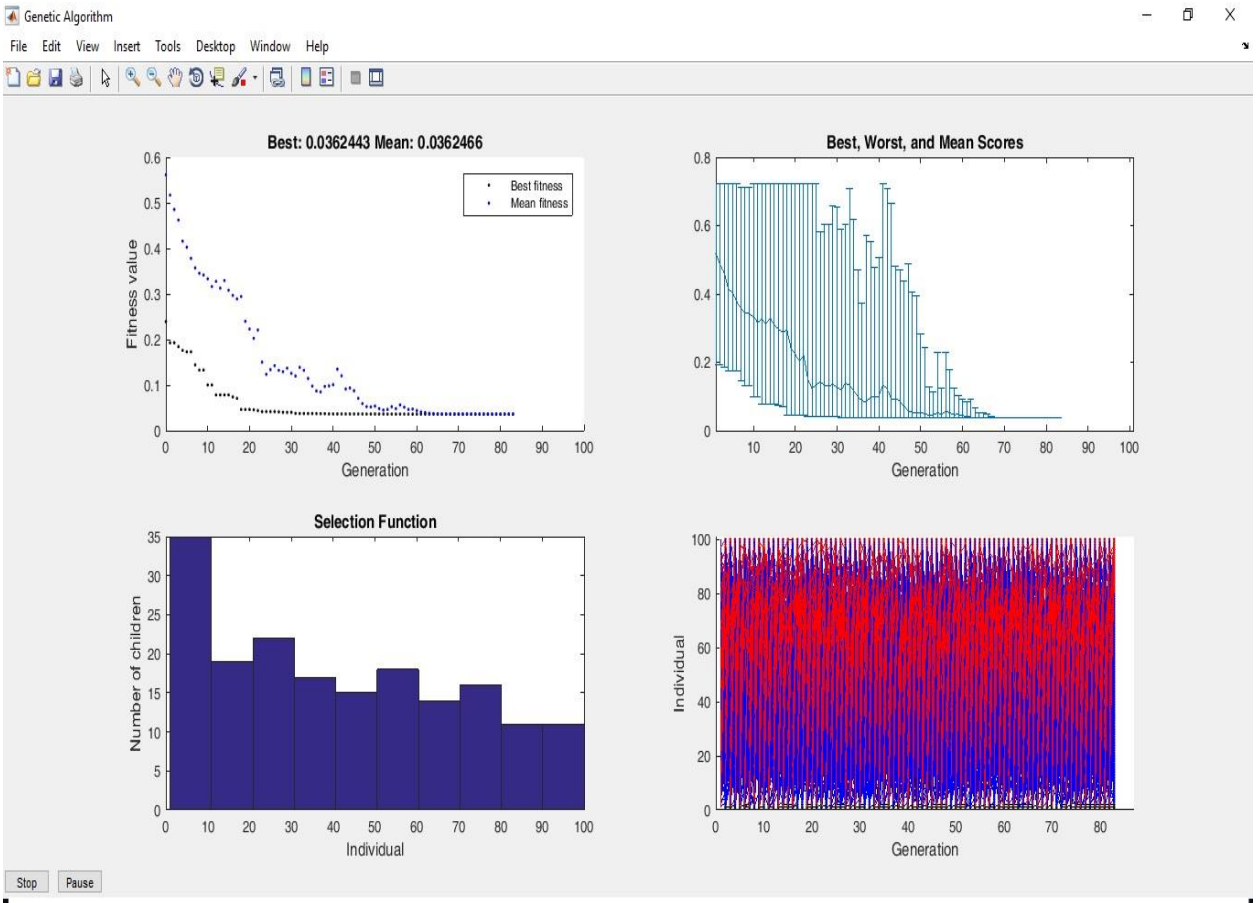

Fig.9 Training dataset Result

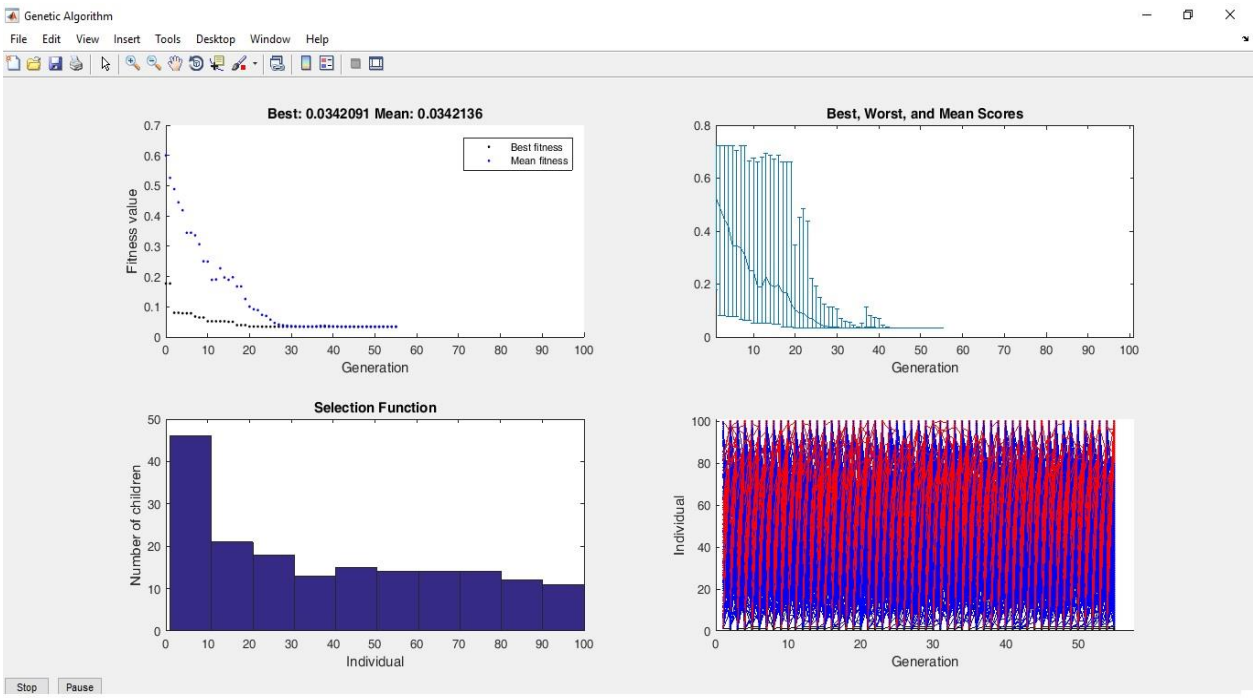

Fig.10 Testing dataset Result

Days	Date	Actual Data	Predicted Data
2025	July 19, 2014	Heavy Rain	Heavy Rain
2026	July 20, 2014	Light Rain	Light Rain
2027	July 21, 2014	No Rain	No Rain
2028	July 22, 2014	Light Rain	Light Rain
2029	July 23, 2014	Light Rain	Light Rain
2030	July 24, 2014	Heavy Rain	Moderate Rain
2031	July 25, 2014	Moderate Rain	Moderate Rain
2032	July 26, 2014	Light Rain	Light Rain
2033	July 27, 2014	Light Rain	Light Rain
2034	July 28, 2014	Light Rain	Light Rain
2035	July 29, 2014	Heavy Rain	Heavy Rain
2036	July 30, 2014	Heavy Rain	Heavy Rain
2037	July 31, 2014	Moderate Rain	Moderate Rain
2038	August 1, 2014	Heavy Rain	Heavy Rain
2039	August 2, 2014	Moderate Rain	Moderate Rain
2040	August 3, 2014	Moderate Rain	Moderate Rain
2041	August 4, 2014	Light Rain	Light Rain
2042	August 5, 2014	Light Rain	No Rain
2043	August 6, 2014	Moderate Rain	Moderate Rain
2044	August 7, 2014	Light Rain	Light Rain
2045	August 8, 2014	Light Rain	No Rain
2046	August 9, 2014	Moderate Rain	Moderate Rain
2047	August 10, 2014	Light Rain	Light Rain
2048	August 11, 2014	Light Rain	Light Rain
2049	August 12, 2014	Moderate Rain	Moderate Rain
2050	August 13, 2014	Light Rain	Light Rain
2051	August 14, 2014	Moderate Rain	Moderate Rain
2052	August 15, 2014	Light Rain	Light Rain
2053	August 16, 2014	Moderate Rain	Moderate Rain

Fig.11 Predicted Result of Training Dataset

Days	Date	Actual Data	Predicted Data
3111	July 9, 2017	No Rain	No Rain
3112	July 10, 2017	No Rain	No Rain
3113	July 11, 2017	Light Rain	Light Rain
3114	July 12, 2017	Light Rain	Light Rain
3115	July 13, 2017	Light Rain	Light Rain
3116	July 14, 2017	Moderate Rain	Moderate Rain
3117	July 15, 2017	No Rain	Light Rain
3118	July 16, 2017	Moderate Rain	Moderate Rain
3119	July 17, 2017	Moderate Rain	Moderate Rain
3120	July 18, 2017	Heavy Rain	Heavy Rain
3121	July 19, 2017	Heavy Rain	Heavy Rain
3122	July 20, 2017	Moderate Rain	Moderate Rain
3123	July 21, 2017	Moderate Rain	Moderate Rain
3124	July 22, 2017	Moderate Rain	Moderate Rain
3125	July 23, 2017	Moderate Rain	Moderate Rain
3126	July 24, 2017	Light Rain	Light Rain
3127	July 25, 2017	Light Rain	Light Rain
3128	July 26, 2017	Light Rain	Light Rain
3129	July 27, 2017	Heavy Rain	Moderate Rain
3130	July 28, 2017	Moderate Rain	Moderate Rain
3131	July 29, 2017	Moderate Rain	Moderate Rain
3132	July 30, 2017	Moderate Rain	Moderate Rain
3133	July 31, 2017	Moderate Rain	Moderate Rain
3134	August 1, 2017	Light Rain	Light Rain
3135	August 2, 2017	Light Rain	Light Rain
3136	August 3, 2017	Light Rain	Light Rain
3137	August 4, 2017	No Rain	No Rain
3138	August 5, 2017	No Rain	No Rain
3139	August 6, 2017	No Rain	No Rain

Fig.12 Predicted Result of Testing Dataset

The above fig. 9 and 10 showed that, how SPM obtained the best member from each generation and reached to the nearest predicted value. It also showed the best and worst value of each generation. The average RMSE value obtained for the best generation of training and testing dataset was 0.0362443 and 0.0342091 respectively. SPM Prediction results obtained from the training and testing dataset was shown in fig.11 and 12 respectively.

5. CONCLUSION

The rainfall trend was analyzed to understand the past and present climatic changes. In this research, monsoon rainfall shows a positive trend for June and July i.e., an increase in rainfall, while a negative trend for the month August and September i.e., a decrease in rainfall. Further, SPM implemented in Matlab used genetic algorithm which predicted the accurate daily rainfall. The SPM performance is judged by the RMSE, which is close to value 0.03, which is good for the accurate rainfall prediction. It provides daily predicted output values in the form of rainfall type. Thus, SPM helps farmers to take crucial farming decisions like the type and time of sowing the crops during the monsoon season.

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