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Rainfall prediction using support vector regression in Udupi region Karnataka, India

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ABSTRACT

The hydromatereological processes are examined through analysis of temporal rainfall variability. India is an agricultural land and its economy is mainly dependent on timely rains to produce good harvest. The amount of rainfall varies with regional and temporal variation in distribution. The present research has been conducted to predict the temporal variations in rainfall in Udupi district, Karnataka, India using support vector regression (SVR) model and to validate the findings using actual rainfall records. The data has been collected from the statistical department, Udupi district, Government of Karnataka, India. The prediction accuracy of SVR based rainfall prediction model depends on tuning of algorithmic-based parameters. The parameter optimization is performed using grid search to select the optimal values of hyperparameters. The analysis was performed for the year 2018 based on the training dataset from 2000-2017. It is observed that there is a decreasing trend in total annual rainfall in 2018 and it is concluded that the average yearly rainfall has declined during the years 2018 and 2019. The rainfall predicted results were validated with actual records. The SVR based rainfall prediction model will predicts the rainfall accurately for application in agricultural sector.

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1. INTRODUCTION

The tropical region like India, the weather prediction is more challenging due to its nearness to the equator causing turbulent and highly variable weather [1]. Advancement in modern environmental science tools such as radar and computer models have increased the ability of meteorologist to forecast the weather with high accuracy. The numerical weather prediction (NWP) models are high-resolution models demonstrate continued improvements [2], [3]. Therefore, forecasting using these NWP models will always have some uncertainty [4]. Currently the Natural Weather Science Committee is searching for the alternative methods to NWP models in which forecasting accuracy is still 60-70% even after the introduction of high-performance computing facility [5]-[7]. The observational approaches focus with atmospheric changes and features in the sky like cloud formation, biological, and phenological indicators which are pointed out by Gadgil *et al.* [8] state the important parameters need to be monitored on time scales of weeks apart from prior to monsoon period but also the evolution of the monsoon in the month of June. Kanani and Pastakita [9] stated that there is a need to validate empirical weather forecasting models using latest machine learning mechanisms for rainfall prediction in the future.

The World Health Organization (WHO) had announced that by 2028 the future war would be on water resources due to the scarcity of drinking water [10], [11]. These numerical models are found to be accurate in the calculation but less efficient to predict irregularly varying patterns of data. The recent ground-water level forecasting models using a data-driven approach are adopted for collecting quantitative historical data to forecasting future trends.

A data driven models have been extensively used by hydrologists mostly in modeling of the rainfall-runoff process and many researchers have made efforts to explore different soft computing-based prediction models. Artificial neural networks (ANN), fuzzy logic, and regression are the mathematical approaches used in these models. Jain and Srinivasalu [12] proposed ANN based rainfall prediction model and predicted rainfall with large dataset. Therefore, these complexities result in uncertainties and results are not stable [13]-[15]. Supreetha *et al.* [16] used swarm intelligence as an alternative optimisation methodology for training ANN to achieve a more stable and efficient result. Supreetha *et al.* [17] investigated recurrent neural network (RNN) long short term memory (LSTM) to forecast time series data. The RNN suffers from the problem of vanishing gradients which can make it difficult to train the network efficiency. They used hybrid approach to resolve the issue.

In order to improve the generalization capability, in the current study support vector regression (SVR) based rainfall prediction model is proposed. Previous studies have shown that data driven approaches have good capabilities to forecast precipitation [18]-[23]. Most of the previous studies on rainfall prediction described soft computing-based rainfall prediction using historical rainfall data; therefore, this has been proven the most significant factor in rainfall prediction [24]-[25]. The availability and utilization of groundwater resources is as shown in Figure 1.

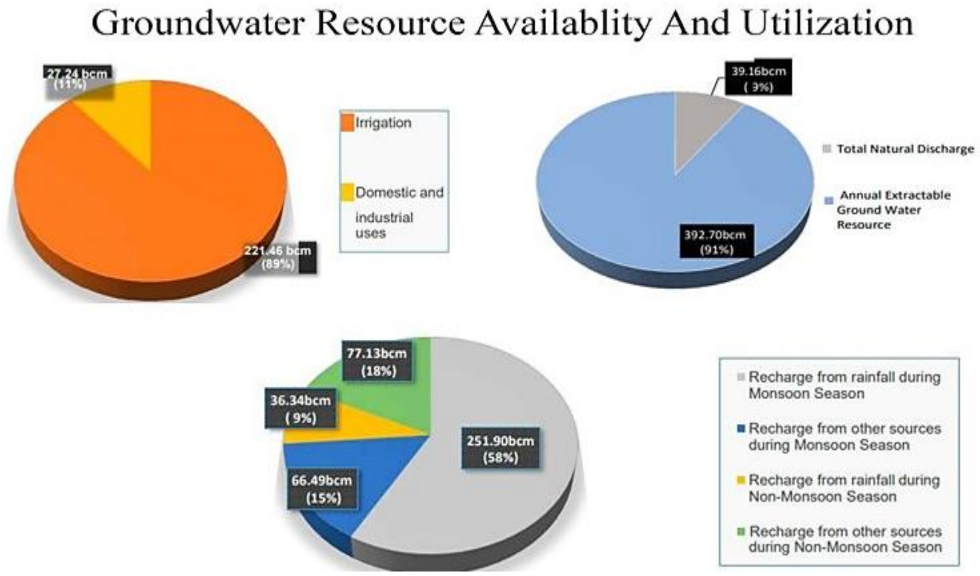


Figure 1. Illustration of utilization of groundwater resources

As per the assessment report of dynamic groundwater resources 2017, the total annual replenishable groundwater resources for the entire country have been assessed [26]-[29]. The groundwater dynamics in Karnataka, there is marginal decrease in annual groundwater recharge, thus the groundwater level in Karnataka is on verge of decline and is likely to face water scarcity in the near future, particularly in the irrigation sector. The groundwater resource availability and utilization in Udupi is as shown in Table 1. The agriculture in Udupi is dependent on monsoon rains for irrigating their crops. The insufficient rainfall can cause crop failure and impact agricultural production. Therefore, there is a need to predict rainfall and adopt proper water resource management strategies. The groundwater resource availability and utilization in Udupi is as shown in Figure 2. The main source of groundwater recharge in Udupi is through rainfall and delayed rainfall has potential impacts on irrigation and finally in agricultural sector. Therefore, predicting rainfall is critical for planning proper groundwater resource management.

Table 1. The groundwater utilization as per CGWB

Status of block as per central groundwater board notification				Groundwater in BCM		
Block name	Critical	Semi critical	Safe	Draft	Recharge	Balance
Udupi	Nil	Nil	Safe	0.0395306	0.0940031	0.0544725
Kundapura	Nil	Nil	Safe	0.0478434	0.0949374	0.0470940
Karkala	Nil	Nil	Safe	0.0330176	0.1388117	0.1057941
Total				0.1203916	0.3277522	0.2073606

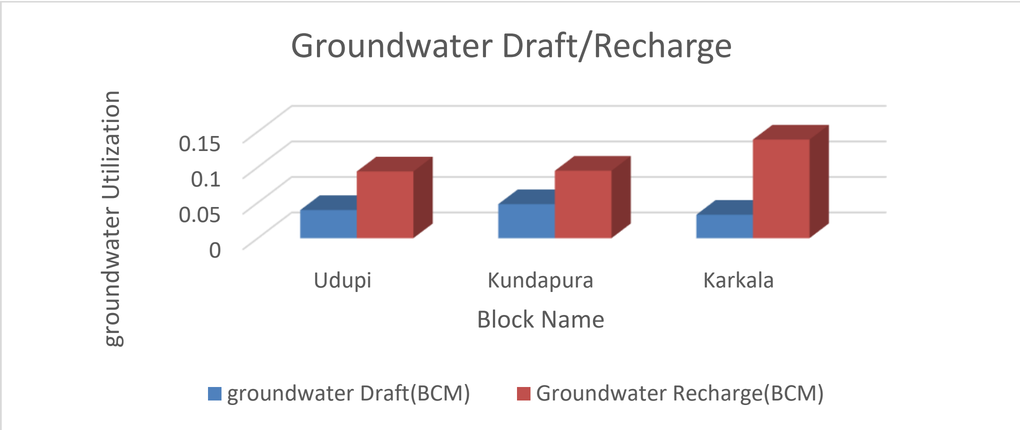


Figure 2. Groundwater resource availability and utilization in Udupi

2. METHOD

2.1. Study area and data

The Udupi district, Karnataka state, India is considered for study and thje study area with location map is as shown in Figure 3. The monthly rainfall data is collected from Statistical Department, Udupi District, Government of Karnataka. The historical rainfall dataset for a period of 2004 to 2018 was used.

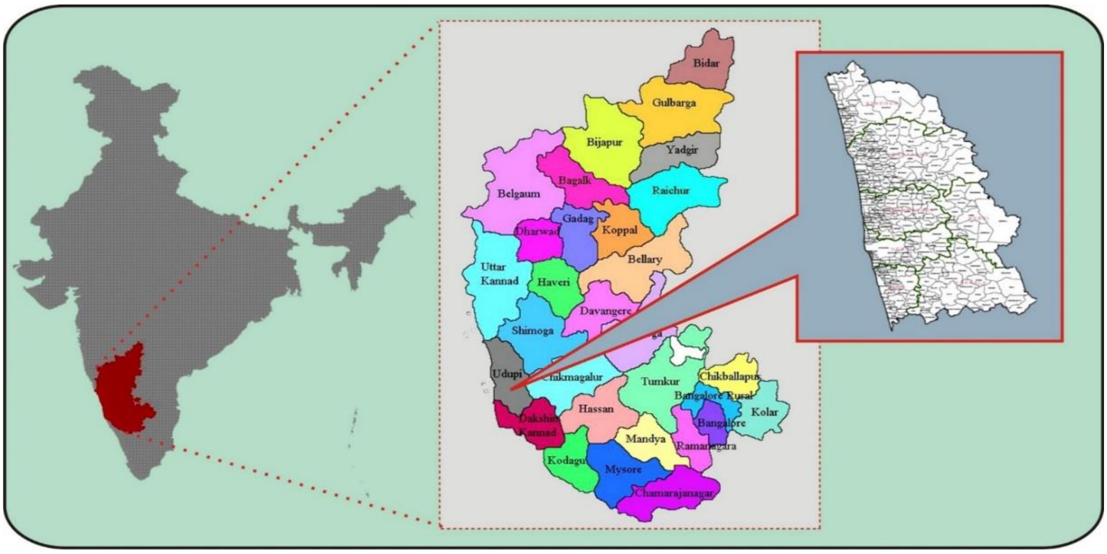


Figure 3. Study area and location map

The groundwater fluctuations in Udupi region is the annual feature due to well-defined seasonal rainfall. The average annual rainfall for the year 2015, 2016, and 2017 were 3,547 mm, 3,741 mm, and 3,994 mm, respectively as shown in Figure 4. The data driven models are specific to the location under study so are applied with the output values only apply to the location where it was developed [30]-[32].

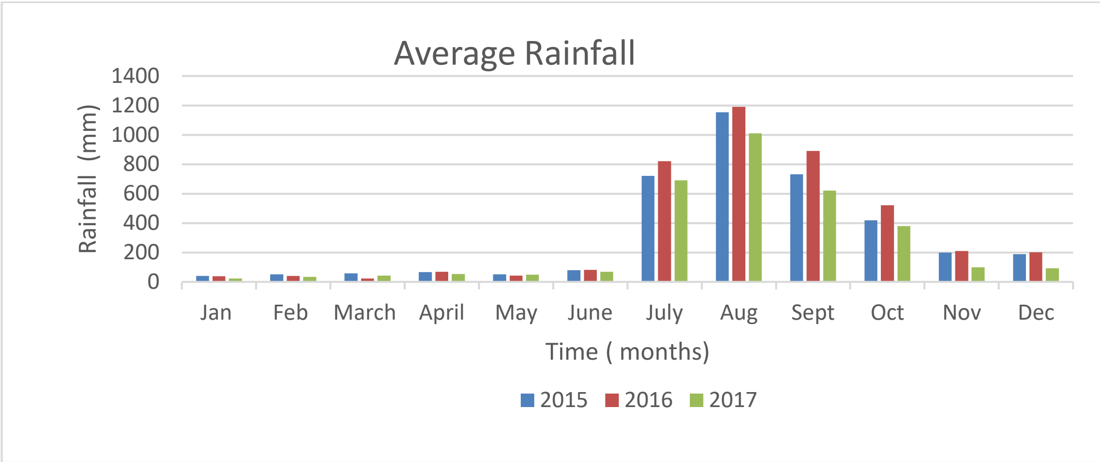


Figure 4. Plot of average annual rainfall

2.2. Support vector regression-based rainfall prediction

The SVR approach that is extension of well-known support vector machine (SVM) algorithm in regression problems. It minimizes the generalization error bound with limited number of learning patterns to achieve generalized performance. It is applied in time series prediction task and it works on subset of the training data called support vectors.

$$\frac{1}{2}\|w\|^2 + C\sum_{i=0}^{m}(\xi + \xi^*)$$

$$\text{Subject to} \begin{cases} yi - \langle w, xi \rangle - b \leq \epsilon i + \boldsymbol{\xi} \\ \langle w, xi \rangle + b - yi \leq \epsilon i + \boldsymbol{\xi}^* \\ \xi_i, \xi_i^* \geq \mathbf{0} \quad \boldsymbol{i} = \mathbf{1}, \ldots . \boldsymbol{m} \end{cases} \tag{1}$$

SVR is a machine learning method that can be applied to rainfall prediction, leveraging its ability to model complex relationships in data and handle nonlinearities. The SVR maps input data to a high-dimensional space using kernel functions and finds a hyperplane that predicts the output with minimal error. The regularization parameter C Controls the trade-off between achieving a low error on the training set and maintaining generalization to unseen data and the epsilon defines a margin of tolerance where predictions are considered acceptable. In (1) describes the formulation of SVR optimization problem, the SVR based rainfall prediction models train and test with the limited dataset and the performance of these forecasting models depends on tuning algorithmic related parameters. The schematic diagram of SVR based rainfall prediction model is as shown in Figure 5.

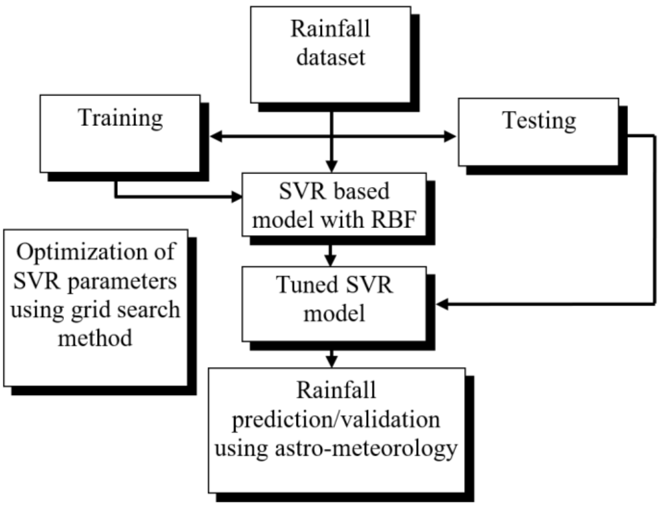


Figure 5. Schematic representation of SVR based rainfall prediction

The model has two important hyperparameters namely C and Ɛ. The parameter C controls the tradeoff between the error of the SVR on training data and marginal maximization. Thus, factor C is a parameter that allows one to tradeoff training error verses models complexity. The second parameter Ɛ denotes how much error is allowed as per training data instance. The cross validation is used to tune these two hyperparameters of SVR and parameter optimization is performed using grid search () to select the best value for C and Ɛ. The nonlinear kernel radial basis function (RBF) was used since it performs better empirically compared to other kernel functions. The root mean squared errror (RMSE) is considered as objective function and the selection of C and Ɛ has been done that it minimizes RMSE. Thus, The RBF kernel trains an SVR with each pair (C, Ɛ) in the cartesian product of these 2 sets and evaluates their performance on a held-out validation set. Thus, finally it outputs the settings that achieved good score in the validation process.

3. RESULTS AND DISCUSSION

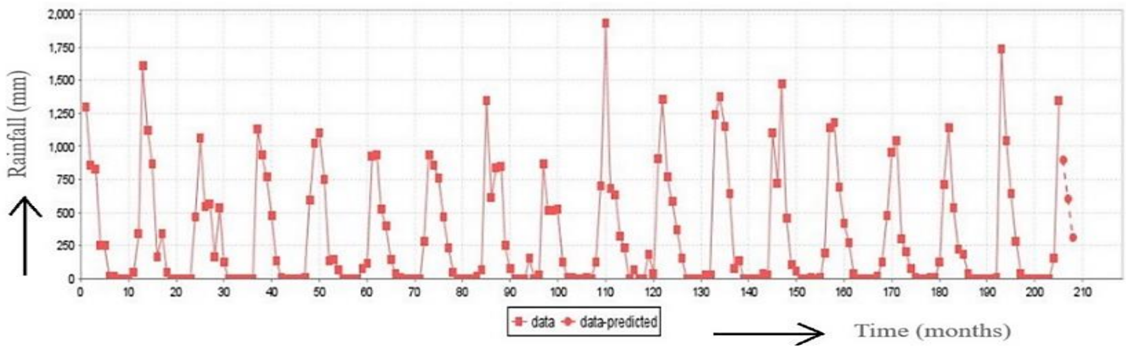
3.1. Performance analysis of support vector regression (SVR) based rainfall prediction model

The aim of using SVR based rainfall prediction model is to forecast the rainfall using historical rainfall data from Udupi region, Karnataka, India. The analysis is being performed for one-year lead time for 2018 (210 months) based on the training dataset for the period 2000-2017 and it is observed that the average yearly rainfall declined during the year 2018 and 2019.

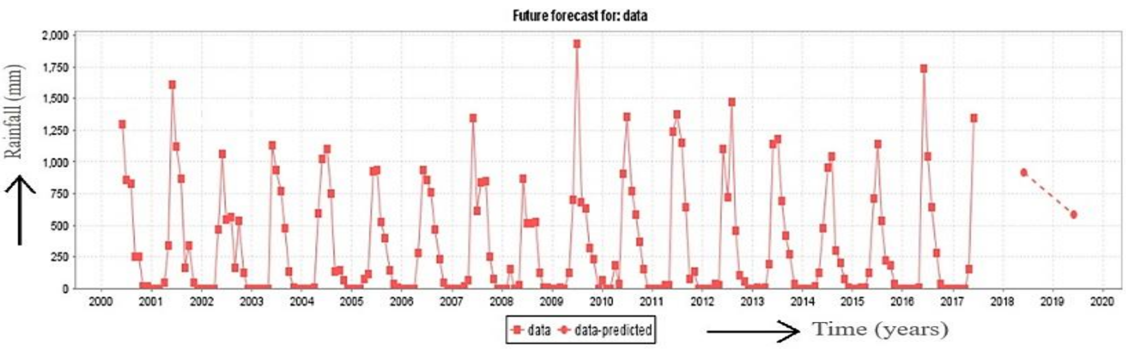
The optimal SVR parameters obtained and corresponding least value of RMSE for the month of May, October, and September 2018 after tuning the SVR parameter is as tabulated in Table 2. The time series plot for predicted rainfall for the pre-monsoon and post-monsoon the dataset from 2000-2016 is presented in Figure 6(a) and (b) respectively. It is observed that there is correlation between actual and predicted rainfall using SVR and tuned SVR model.

Table 2. Optimal SVR hyperparameters

	Optimal values		
	C	Ɛ	RMSE
May	8	0.1	146.40
October	64	0.1	103.67
September	4	0.0	128.84



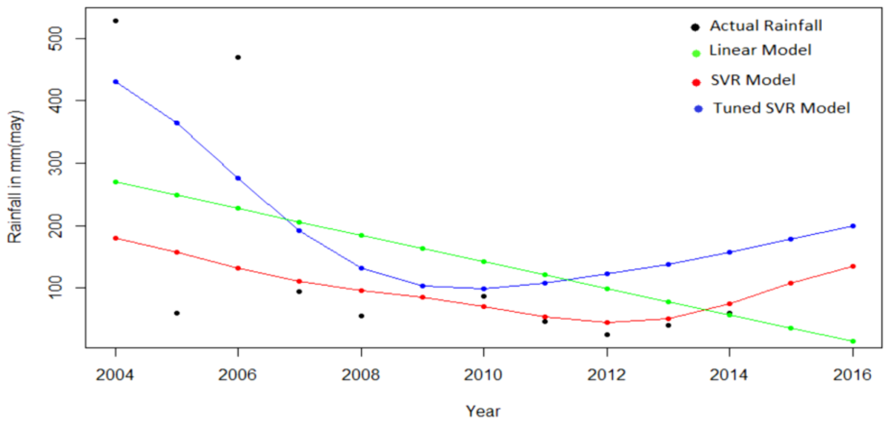
(a)



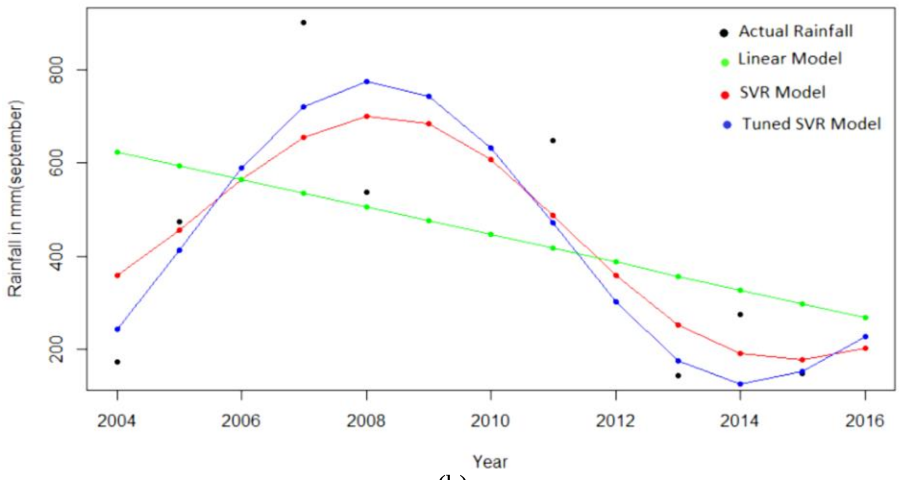
(b)

Figure 6. Forecasted yearly rainfall for one-year lead time: (a) pre-monsoon and (b) post-monsoon

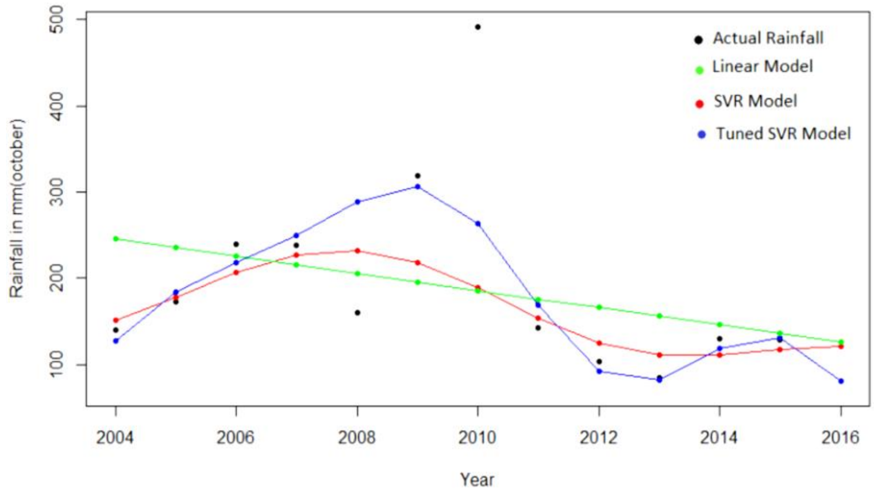
The time series plot for predicted rainfall for month May, October, and September for the dataset from 2000-2016 is presented in Figure 7(a) to (c) respectively. It is observed that there is a strong correlation between tuned SVR prediction with the actual records.



(a)



(b)



(c)

Figure 7. Rainfall prediction using SVR based model: (a) month of May, (b) month of September, and (c) month of October

3.2. Statistical results of rainfall prediction model

Table 3 presents the statistical results of the rainfall prediction model developed for the month of May, September, and October and the corresponding plot is presented in Figure 8. The error values using above statistical indices shows the global goodness of fit between the computed and observed rainfall records for all the three cases. Therefore, it is inferred that tuned SVR model shows good performance.

Table 3. Statistical results of rainfall prediction model

	May			September			October		
	Linear	SVR	Tuned SVR	Linear	SVR	Tuned SVR	Linear	SVR	Tuned SVR
Relative absolute error	52.861	36.409	45.729	57.678	38.986	43.456	37.657	37.678	42.456
Mean absolute percentage error	7.966	8.982	9.234	8.345	9.765	8.987	7.765	7.986	8.789
RMSE	0.934	1.03	0.926	0.965	1.091	0.912	0.954	1.08	0.9253
Mean absolute error	0.7321	0.8723	0.7942	0.678	0.789	0.7954	0.623	0.873	0.934

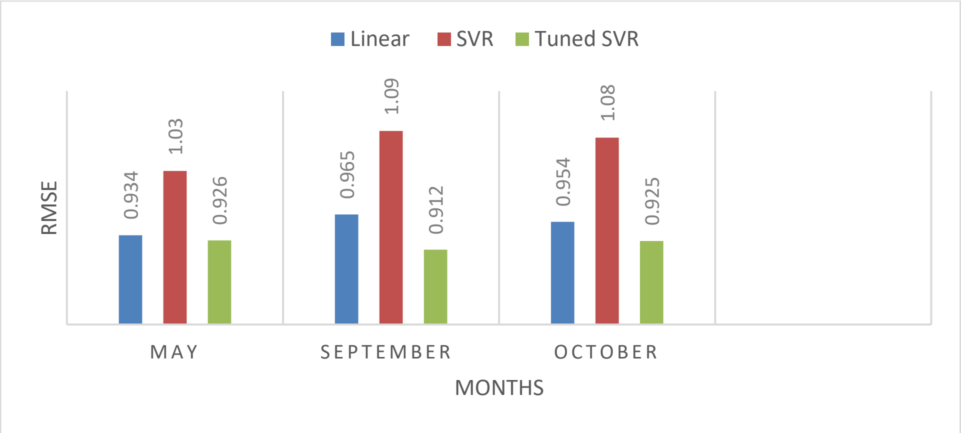


Figure 8. Plot of RMSE for SVR based model

The predicted rainfall records are validated with the actual records and as per the Indian Meteorological Department (IMD) there was a heavy rain and terrible downpour had taken place from August 12th to 15th and a lot of destruction happened in coastal areas. The maximum rain of around 1367.0 mm recorded by IMD in the month of Aug 2018. Therefore, it is concluded the overall rainfall in 2018 would be average and with high variation as was observed in Udupi region.

4. CONCLUSION

The present research work introduces SVR based rainfall prediction model for predicting rainfall of Udupi region, Karnataka state, India. The results of SVR based rainfall prediction model are validated using actual rainfall records. The rains will be evenly spread in July to September 2018 and from in august month very heavy rain with storm observed in Udupi region which was validated using actual records. The main limitation of this study is there is no consistent rainfall observed in Udupi region for the study period and which affects the accuracy of the model. Based on our finding we concluded that rainfall prediction there is strong correlation between SVR based prediction and actual records Thus, the overall rainfall in 2018 would be average and with high variation as was observed in Udupi region.

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