Forecast of Rainfall Quantity and its Variation using Environmental Features

Preetham Ganesh[1], Harsha Vardhini Vasu[2], Dayanand Vinod[3]

Department of Computer Science and Engineering
Amrita School of Engineering, Coimbatore
Amrita Vishwa Vidyapeetham, India

preetham.ganesh2015@gmail.com[1], *harshavardhini2019@gmail.com*[2],
v_dayanand@cb.amrita.edu[3]

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Overview

Abstract

- Rainfall plays a crucial role in the lives of an ordinary man.
- Developing a prediction model that captures sudden fluctuations in rainfall has always been a challenging task.
- The paper aims at developing three models which predict monthly rainfall for all districts in Tamil Nadu, India and also drawing a district-wise comparison among them to find the best model for prediction.
- The models developed are District-Specific Model, Cluster-Based Model and Generic-Regression Model.

Abstract

- The District-Specific Model trains on data from a particular district, the Cluster-Based Model groups districts based on the climatic conditions and trains on data from a particular cluster and the Generic-Regression Model trains on combined data from all the districts.
- The paper also aims at finding the monthly variation of rainfall across geographical regions.

Introduction

- Agriculture is the backbone of India's economy.
- Rainfall is the central source of water for the country's agricultural land.
- It is a boon if the rainfall quantity is in the right amount and a bane if the rainfall is too low or too high where the crops get destroyed.
- The knowledge about the rainfall quantity and its variation can help the farmers to plan their crops, thus saving time, effort and resources.
- These preventive measures can not only save human lives but can also minimise the recovery and reconstruction costs for the state.

Contributions

- The primary focus is on finding the best model among the District-Specific Model, Generic-Regression Model and the Cluster-Based Model along with the best regression algorithm and the corresponding parameter for each district.
- Also, to optimise the result, different parameters for each regression algorithm across all the models are tested.
- Section 6 discusses the variation of rainfall across the geographic regions

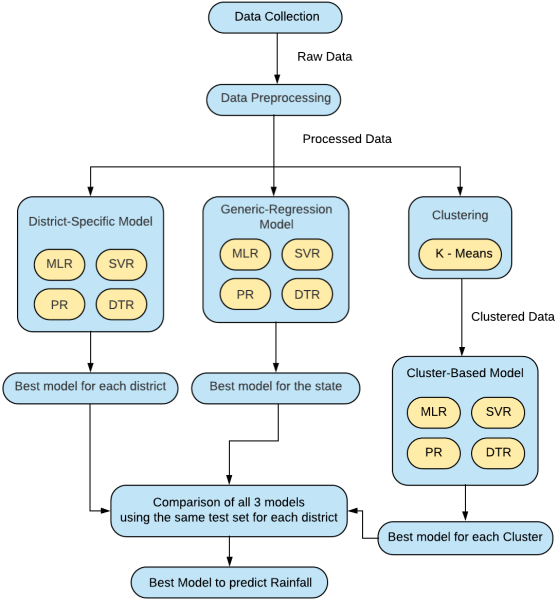
Dataset Description

- The India Water Portal - Met Data Repository is used to collect the data.
- **Independent Attributes**:
  - Average Temperature
  - Cloud Cover
  - Maximum Temperature
  - Minimum Temperature
  - Crop Evapotranspiration
  - Potential Evapotranspiration
  - Vapor Pressure
  - Wet Day Frequency
- **Dependent attribute** - Rainfall

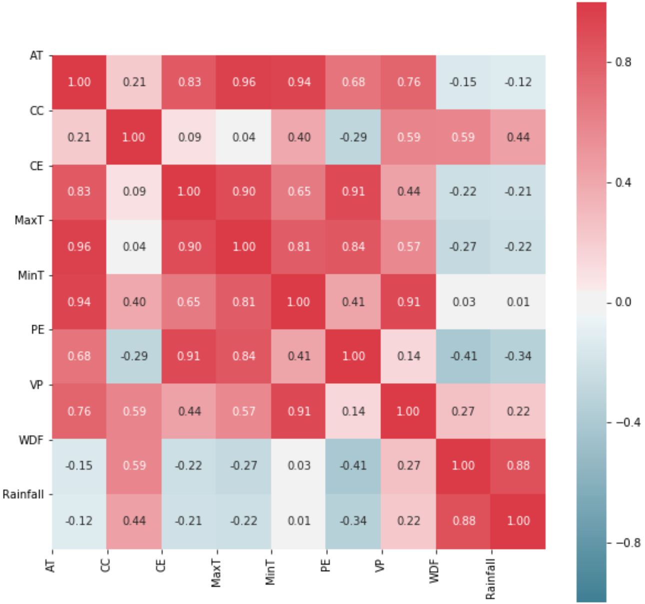
Algorithms and Error Measures

- **Regression Algorithms**
    - Multiple Linear Regression (MLR)
    - Support Vector Regression (SVR)
    - Polynomial Regression (PR)
    - Decision Tree Regression (DTR)
- **Clustering Algorithm**
    - K-Means Clustering
- **Error Measures**
    - Mean Sqaured Error (MSE)
    - Root Mean Squared Error (RMSE)
    - Mean Absolute Error (MAE)
    - Median Absolute Error (MDAE)
    - Explained Variance Score (EVS)
    - R^2 Score (R^2)

Process Flow



Correlation Heat Map



Performance of District-Specific Model

Method	Parameter	MSE	RMSE	MAE	MDAE	EVS	R^2
Multiple Linear Regression	-	0.004	0.0635	0.0442	0.0324	0.8257	0.8241
Polynomial Regression	**Degree = 2**	**0.0039**	**0.0615**	0.0423	0.0282	**0.8305**	**0.8289**
	Degree = 3	0.004	0.0629	**0.0402**	**0.0239**	0.8273	0.8253
	Degree = 4	0.0558	0.1933	0.0846	0.0408	-1.5956	-1.6172
	Degree = 5	4149.7	50.1	15.3	2.7	-187415	-188520
Decision Tree Regression	Max Depth = 2	0.0057	0.0747	0.0484	0.0252	0.7569	0.7552
	Max Depth = 3	0.0043	0.0646	0.0393	0.0198	0.817	0.8156
	Max Depth = 4	0.004	0.0628	0.0371	0.0183	0.8278	0.8264
	Max Depth = 5	**0.0039**	**0.0616**	**0.036**	**0.0181**	**0.8342**	**0.833**
	Max Depth = 6	0.0042	0.0639	0.0368	0.0184	0.8211	0.8199
	Max Depth = 7	0.0044	0.0653	0.0374	0.0184	0.8132	0.812
Support Vector Regression	Kernel = Linear	0.0046	0.0674	0.05	0.0406	0.8053	0.8002
	Kernel = Poly	0.0103	0.1004	0.0727	0.0592	0.5758	0.5637
	Kernel = RBF	**0.0038**	**0.0609**	**0.0424**	**0.031**	**0.8395**	**0.8372**
	Kernel = Sigmoid	0.2638	0.5119	0.3532	0.2414	-10.41	-10.93

Figure: Comparison on performance of the regression algorithms for the Chennai District

Performance of the Generic-Regression Model

Method	Parameter	MSE	RMSE	MAE	MDAE	EVS	R^2
Multiple Linear Regression	-	0.0006	0.0254	0.0156	0.0101	0.7845	0.7844
Polynomial Regression	Degree = 2	0.00057	0.0239	0.0145	0.0089	0.8081	0.8081
	Degree = 3	0.00054	0.0231	0.0137	0.0079	0.8207	0.8206
	Degree = 4	**0.00052**	**0.0227**	**0.0134**	**0.0076**	**0.8268**	**0.8267**
	Degree = 5	0.00053	0.0229	0.0135	0.0078	0.8236	0.8235
Decision Tree Regression	Max Depth = 2	0.00098	0.0313	0.0192	0.0111	0.6731	0.673
	Max Depth = 3	0.00074	0.0272	0.016	0.0091	0.7518	0.7518
	Max Depth = 4	0.00067	0.0259	0.0149	0.0083	0.7759	0.7758
	Max Depth = 5	0.00064	0.0253	0.0145	0.0081	0.7862	0.7862
	Max Depth = 6	**0.00063**	**0.0252**	**0.0142**	**0.0079**	**0.7878**	**0.7877**
	Max Depth = 7	0.00065	0.0254	**0.0142**	**0.0079**	0.7833	0.7833
Support Vector Regression	**Kernel = Linear**	**0.0015**	**0.0388**	**0.0311**	**0.0279**	0.6963	**0.494**
	Kernel = Poly	0.0041	0.0641	0.0574	0.0577	0.5824	-0.3829
	Kernel = RBF	0.0027	0.0523	0.0463	0.0466	0.6845	0.0814
	Kernel = Sigmoid	0.0016	0.0394	0.033	0.0318	**0.7475**	0.4795

Figure: Comparison on performance of the regression algorithms for the Generic-Regression Model

Cluster-Based Model

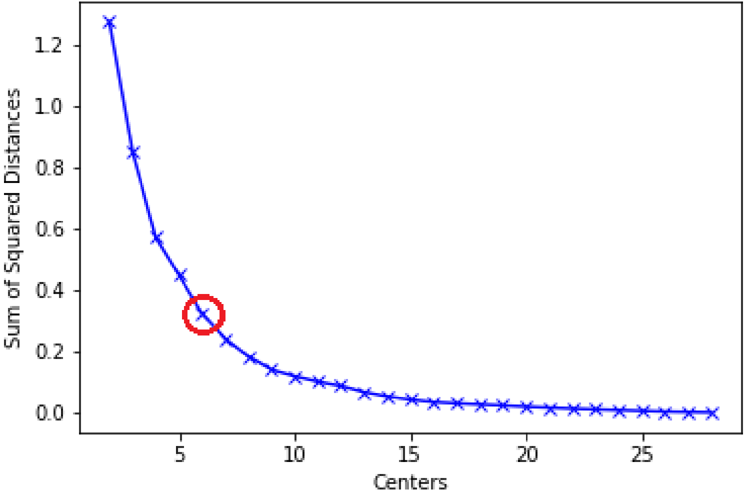
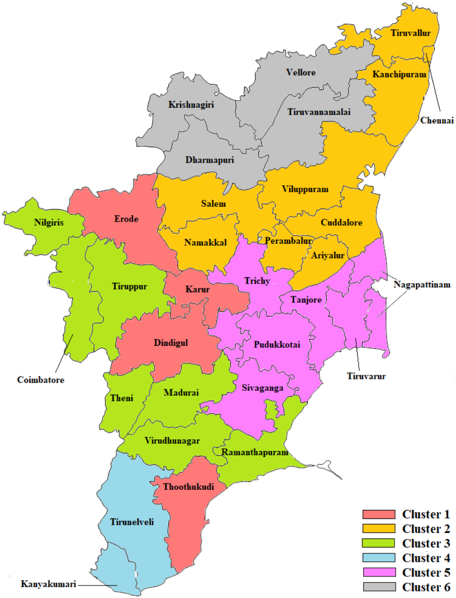


Figure: Elbow Method

Graphical Representation of formed Clusters



Performance of Cluster-Based Model

Method	Parameter	MSE	RMSE	MAE	MDAE	EVS	R^2
Multiple Linear Regression	-	0.0044	0.0663	0.0462	0.0309	0.7412	0.7406
Polynomial Regression	Degree = 2	0.0043	0.0654	0.0453	0.0307	0.748	0.7475
	Degree = 3	**0.0041**	**0.0635**	**0.0437**	**0.029**	**0.7624**	**0.7619**
	Degree = 4	0.0044	0.0659	0.0454	0.0304	0.7444	0.7438
	Degree = 5	0.0106	0.1005	0.0604	0.0.0384	0.379	0.3777
Decision Tree Regression	Max Depth = 2	0.0056	0.0745	0.0534	0.0363	0.6729	0.6722
	Max Depth = 3	0.0048	0.069	0.0478	0.0325	0.7193	0.7187
	Max Depth = 4	0.0047	0.0682	0.0463	0.0309	0.7257	0.7251
	Max Depth = 5	**0.0046**	**0.0678**	**0.0454**	0.0299	**0.7287**	**0.7282**
	Max Depth = 6	0.0048	0.0688	0.0456	**0.0295**	0.7204	0.7198
	Max Depth = 7	0.005	0.0705	0.0463	0.0296	0.7062	0.7056
Support Vector Regression	**Kernel = Linear**	**0.0048**	**0.0694**	**0.0526**	**0.0419**	**0.7343**	**0.7162**
	Kernel = Poly	0.0068	0.0824	0.0675	0.0641	0.6359	0.6001
	Kernel = RBF	0.005	0.071	0.0557	0.0469	0.7292	0.7031
	Kernel = Sigmoid	0.7071	0.8392	0.5115	0.3084	-38.35	-40.84

Figure: Comparison on performance of the regression algorithms for the Cluster 1

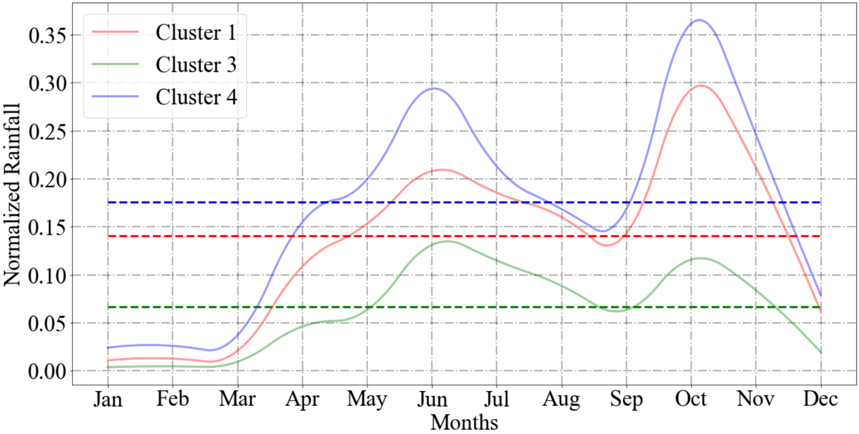
Comparison between the models using MSE, RMSE and MAE

Cluster	District Name	MSE			RMSE			MAE		
		District	Cluster	Generic	District	Cluster	Generic	District	Cluster	Generic
Cluster 1	Dindigul	0.0064	0.0055	**0.0006**	0.0796	0.0734	**0.0245**	0.0559	0.0505	**0.0166**
	Erode	0.0042	0.0026	**0.0003**	0.064	0.0503	**0.0165**	0.0435	0.0338	**0.0109**
	Karur	0.0114	0.0031	**0.0003**	0.1064	0.0555	**0.0184**	0.0778	0.0398	**0.0131**
	Thoothukkudi	0.0074	0.0029	**0.0003**	0.0857	0.0533	**0.0177**	0.0593	0.0369	**0.0121**
Cluster 2	Ariyalur	0.003	0.0008	**0.0001**	0.0539	0.0275	**0.0107**	0.0356	0.0179	**0.0069**
	Chennai	0.0031	0.0022	**0.0003**	0.055	0.0466	**0.0183**	0.0353	0.0287	**0.0112**
	Cuddalore	0.002	0.0005	**0.0001**	0.0441	0.0231	**0.0093**	0.0286	0.0146	**0.0059**
	Kancheepuram	0.0041	0.0017	**0.0003**	0.0634	0.0413	**0.0165**	0.0456	0.0261	**0.0103**
	Namakkal	0.008	0.0012	**0.0002**	0.0891	0.0346	**0.0132**	0.0646	0.0247	**0.0094**
	Perambalur	0.0045	0.0013	**0.0002**	0.0669	0.0352	**0.0134**	0.0453	0.0239	**0.0091**
	Salem	0.0071	0.0011	**0.0002**	0.084	0.0333	**0.0127**	0.0593	0.0229	**0.0087**
	Thiruvallur	0.0046	0.0016	**0.0002**	0.0674	0.0396	**0.0155**	0.0486	0.0253	**0.0098**
	Viluppuram	0.002	0.0005	**0.0001**	0.0441	0.0223	**0.0086**	0.0298	0.0148	**0.0057**
Cluster 3	Coimbatore	0.0035	**0.0009**	**0.0009**	0.059	0.0301	**0.0295**	0.0385	0.0193	**0.0187**
	Madurai	0.007	**0.0008**	**0.0008**	0.0827	**0.028**	**0.028**	0.0546	0.0183	**0.018**
	Ramanathapuram	0.0061	**0.0003**	**0.0003**	0.0776	**0.018**	**0.018**	0.0542	0.0122	**0.012**
	Theni	0.0051	0.0018	**0.0017**	0.0703	0.0412	**0.0411**	0.0433	0.0248	**0.0245**
	The Nilgiris	0.0025	0.002	**0.0019**	0.0486	0.0436	**0.0428**	0.0253	0.0224	**0.0214**
	Virudhunagar	0.0088	**0.0007**	**0.0007**	0.0927	**0.0266**	0.0269	0.0621	0.0176	**0.0175**
Cluster 4	Tirunelveli	0.0082	0.0075	**0.0005**	0.09	0.0856	**0.0228**	0.0611	0.0577	**0.0154**
Cluster 5	Nagapattinam	0.0032	0.0024	**0.0002**	0.0563	0.0489	**0.0151**	0.0378	0.0324	**0.0101**
	Pudukkottai	0.004	0.0019	**0.0002**	0.0625	0.0434	**0.0137**	0.0425	0.0292	**0.0092**
	Sivaganga	0.0048	0.0024	**0.0002**	0.0686	0.0485	**0.0152**	0.0483	0.0337	**0.0105**
	Thanjavur	0.0044	0.0024	**0.0002**	0.0656	0.0483	**0.0149**	0.044	0.032	**0.0098**
	Thiruvarur	0.0054	0.0041	**0.0004**	0.0733	0.0636	**0.0198**	0.0514	0.0426	**0.0132**
	Tiruchirapalli	0.0063	0.0021	**0.0002**	0.0787	0.0458	**0.0143**	0.0576	0.0326	**0.0101**
Cluster 6	Dharmapuri	0.0056	0.0032	**0.0002**	0.0744	0.0566	**0.0125**	0.053	0.0382	**0.0084**
	Tiruvannamalai	0.0054	0.004	**0.0002**	0.0735	0.0628	**0.014**	0.0523	0.0416	**0.0091**
	Vellore	0.0074	0.0049	**0.0002**	0.0854	0.0696	**0.0153**	0.0612	0.0467	**0.0102**

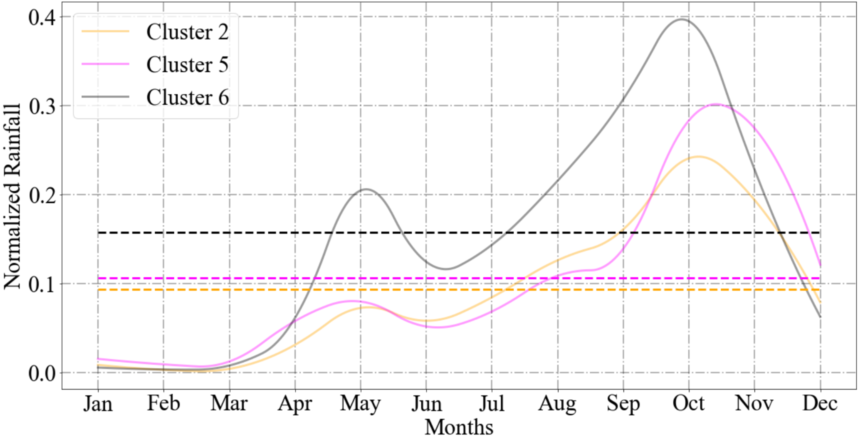
Comparison between the models using MDAE, EVS and R^2

Cluster	District Name	MDAE			EVS			R^2		
		District	Cluster	Generic	District	Cluster	Generic	District	Cluster	Generic
Cluster 1	Dindigul	0.0379	0.0336	**0.0112**	0.7174	**0.7589**	0.7527	0.7146	**0.7571**	0.7508
	Erode	0.0279	0.0212	**0.0069**	0.8407	**0.8654**	**0.8654**	0.8395	0.8643	**0.8646**
	Karur	0.057	0.0268	**0.009**	0.6979	**0.7445**	0.7383	0.6945	**0.7424**	0.7355
	Thoothukkudi	0.0421	0.0251	**0.0081**	0.7018	**0.75**	0.7446	0.6987	**0.7478**	0.7423
Cluster 2	Ariyalur	0.0237	0.0109	**0.0042**	0.8882	**0.9187**	0.9069	0.8873	**0.9181**	0.9062
	Chennai	0.0206	0.0155	**0.0058**	0.8663	**0.9033**	0.8894	0.865	**0.9024**	0.8884
	Cuddalore	0.0186	0.0087	**0.0035**	0.9374	**0.9573**	0.948	0.9369	**0.9569**	0.9475
	Kancheepuram	0.0351	0.0146	**0.0055**	0.8517	**0.916**	0.9016	0.8495	**0.9153**	0.9006
	Namakkal	0.0448	0.0166	**0.0062**	0.7828	**0.8286**	0.8135	0.7803	**0.8273**	0.8117
	Perambalur	0.0283	0.0151	**0.0058**	0.8059	**0.8409**	0.8273	0.8045	**0.8398**	0.8258
	Salem	0.0394	0.0149	**0.0055**	0.7982	**0.8406**	0.8289	0.7963	**0.8391**	0.8274
	Thiruvallur	0.0357	0.0145	**0.0056**	0.8243	**0.9043**	0.8909	0.8227	**0.9035**	0.8901
	Viluppuram	0.0193	0.009	**0.0034**	0.9386	**0.9568**	0.9521	0.9381	**0.9565**	0.9517
Cluster 3	Coimbatore	0.0232	0.0112	**0.0107**	0.8636	0.8847	**0.8888**	0.8625	0.8839	**0.888**
	Madurai	0.0348	0.0115	**0.011**	0.6421	**0.6847**	0.6822	0.639	**0.6814**	0.6797
	Ramanathapuram	0.038	0.0081	**0.0076**	0.7631	**0.8117**	0.8103	0.761	**0.81**	0.8092
	Theni	0.026	0.0145	**0.0138**	0.7353	0.7668	**0.7679**	0.7329	0.7648	**0.7664**
	The Nilgiris	0.0116	0.0099	**0.0085**	0.8494	0.8785	**0.8817**	0.8483	0.8774	**0.8809**
	Virudhunagar	0.0417	0.0115	**0.0112**	0.6459	0.6991	**0.6934**	0.6423	**0.6968**	0.6907
Cluster 4	Tirunelveli	0.0407	0.0388	**0.01**	0.6777	0.7094	**0.7374**	0.6736	0.7069	**0.7348**
Cluster 5	Nagapattinam	0.0247	0.0204	**0.0065**	0.8671	0.8862	**0.8875**	0.8658	0.8853	**0.8866**
	Pudukkottai	0.0275	0.018	**0.0057**	0.8381	**0.8579**	0.8532	0.8368	**0.8567**	0.8523
	Sivaganga	0.0333	0.022	**0.0069**	0.8038	**0.8321**	0.8254	0.8021	**0.8306**	0.8239
	Thanjavur	0.028	0.0198	**0.006**	0.8167	0.8446	**0.8453**	0.8152	0.8434	**0.8442**
	Thiruvarur	0.0359	0.0266	**0.0081**	0.7617	**0.8242**	0.8196	0.7598	**0.8224**	0.8181
	Tiruchirapalli	0.0416	0.0227	**0.0069**	0.7559	**0.8034**	0.8022	0.7528	**0.8019**	0.8
Cluster 6	Dharmapuri	0.0363	0.023	**0.005**	0.7909	**0.8504**	0.8448	0.7894	**0.8493**	0.8439
	Tiruvannamalai	0.0379	0.0251	**0.0053**	0.8366	**0.879**	0.873	0.8352	**0.878**	0.872
	Vellore	0.0448	0.0272	**0.0059**	0.7833	**0.8396**	0.8343	0.7817	**0.8385**	0.8332

Variation of Rainfall across months for Clusters 1, 3 and 4



Variation of Rainfall across months for Clusters 2, 5 and 6



Conclusion

- Based on the analysis, it was observed that the Generic-Regression Model using Polynomial Regression with degree 4 outperforms all the other models and predicts the rainfall in all the districts with comparatively low error rates.
- However, the Cluster-Based Model using Polynomial Regression captures variation in most of the districts and performs better than the Generic-Regression Model only by a fractional value.
- Hence, it can be concluded that Generic-Regression Model is the best model to predict rainfall for the state of Tamil Nadu, India.

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