IMPROVED FRAMEWORK FOR MODELING MUNICIPAL RESIDENTIAL WATER CONSUMPTION ESTIMATION USING WAVELET-MAMDANI FUZZY APPROACH

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ABSTRACT

It is crucial to estimate the residential water consumption in an urban area as accurately as possible in order to result in reliable simulation models. In this research work, hybrid Fuzzy Wavelet (Denoise) technique has been proposed and used for municipal residential water consumption estimation using climatic variables includes rainfall, maximum temperature, minimum temperature and relative humidity for an urban residential area in a Yelahanka City, Bangalore, India. For this purpose historical climatic and water consumption data were collected for a period of ten years. The Developed Fuzzy-wavelet Denoiseis compared with single Fuzzy model. Denoise is done after the wavelet transformation using various mother wavelets such as Haar, Daubechies of order 2 to 6 for different levels with Shannon entropy. After Denoise process, coefficient having useful information is saved and corresponding its statistical properties is transferred to the fuzzy system for better input-output mapping. The performances of the developed models were evaluated using different performance Evaluation indices. The result indicates that detecting non-linear aspect and selecting an appropriate normalizing technique were beneficial in improving the estimation accuracy of the Fuzzy-Wavelet model. It may be concluded that Fuzzy Wavelet Denoise technique has promising potential and applicability in the estimation of Municipal water consumption estimation with high accuracy.

Keywords:Climatic variable, Denoise, Fuzzy Logic, Fuzzy-wavelet, Residential water.

I. INTRODUCTION

In India, Urbanization process is so rapid and sustainable development of cities in an urban area depends on availability of water and uncertainties are associated with climatic change, andother various [10]. It is necessary to study the urbanization process, water shortage and water environment changes to discuss the interaction of urbanization and water utilities. So scientific way of water consumption estimation is a key for urban planning. Accurate estimation of water demand are required as input for proper supply system development and further expansion. It is necessary to understand the water consumption pattern in urban area in different climatic condition, ([6] and in different climatic seasons Hence it is necessary to identify significant impact of short term climate variables on residential water consumption [15]. The above factors show that water consumption is dynamic in nature and Proper understanding of drivers of residential water demand is very essential in managing water resources and also very important in the region of limited resources. Total demand on an urban water distribution system is a time varying, periodic and nonstationary series. Hence proper method is necessary to forecast. But Conventional time series modeling have served the scientific community for a long time and provide reasonable accuracy, and suffer from the assumption of stationery and linearity [9]. This dynamic aspect of the data should be model apart from physical process. Artificial Intelligence techniques such as Fuzzy Logic, ANN, Genetic programming has been reported for analyzing stationary and non-stationary series. But it is observed from the literatures, single artificial Intelligence techniques alone is not sufficient to solve the complex problem which includes missing data, limited data, because those data are noisier. It is necessary to develop powerful hybrid tool in order to reduce the noise, so that accuracy of the model will be improved compare to the accuracy obtained from the single technique. An alternative technique, based on multiresolution fuzzy technique, which is also called as fuzzy-wavelet technique is, employed which results in greatly contributed to transfer the knowledge. Hence more focus should be given to Hybrid approaches to overcome the drawbacks of traditional methods. In this research work a new Hybrid approached is developed, which includes the discrete wavelets transform Denoised approach, which is coupled with fuzzy logic method to improve the accuracy of the estimation and result are compared to single and other hybrid methods.

II. STUDY AREA

The present study covers 4^{th} ward of Yelahanka city, which is a suburban of Bangalore city in the State of Karnataka. Population of Yelahanka increasing in an exponential manner as shown in the figure 1.The summer season starts from March to mid-May, with a temperature in the range 20^0C- 35^0C results higher water consumption during this period. At the end of May, the monsoon season starts and lasts until the end of September. There are about 1140mm of rainfall annually. Yelahanka is served by both south west as well as south east monsoon. Winters are mild and start from November to February, with a temperature in the range 14^0 C to 24^0C. The current water supply to the ward includes several ground water developments and also from the surface sources. Water consumption data were collected from Bangalore water supply authorities (BWSSB) on monthly basis from the year 2004 March to 2014 December. Climatic data were collected from Disaster management cell Yelahanka. Selection of variables is done using correlation coefficient.

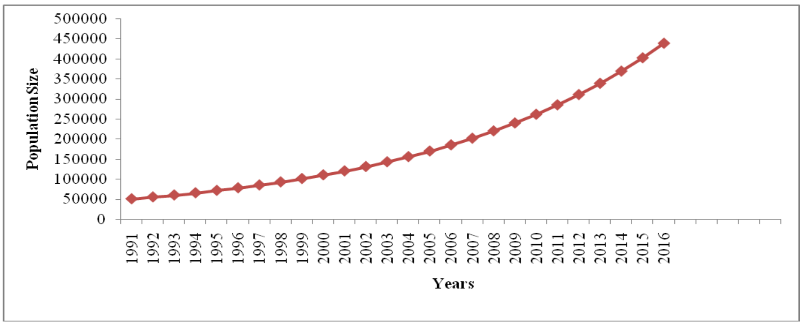

Figure1: Population Statistics (2001 to 2016)

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III. METHODOLOGY

The Methodology adopted for this research work is shown in the figure 2 and model developed using various input scenarios is represented in the table 1.

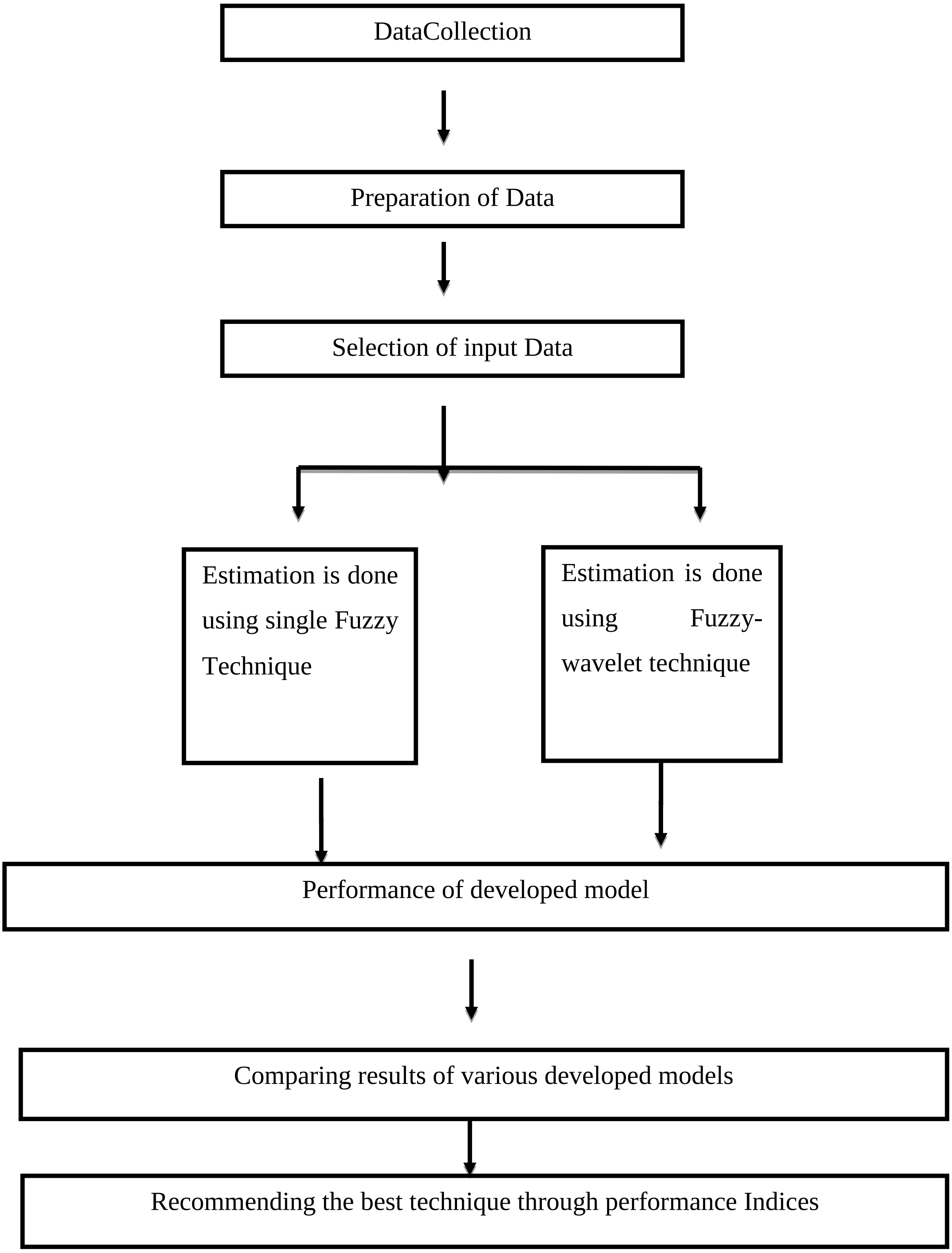

Figure2: Methodology Adopted

FW: Fuzzy Wavelet

FWD: Fuzzy Wavelet Denoised

Table1: Model Development

Model Type	Inputs	Output
	Rainfall	WC
	Maximum Temperature	WC
	Minimum Temperature	WC
Fuzzy Model	Relative Humidity	WC
Fuzzy Wavelet Denoised (FWD) Including Haar, Daubechies family groups of different levels	Rainfall	WC
	Maximum Temperature	WC
	Minimum Temperature	WC
	Relative Humidity	WC

WC: Water consumption

IV. RESULTS AND DISCUSSIONS

Table 2, shows the results of Fuzzy model for four different inputs such as Rainfall, Maximum temperature, minimum temperature and relative humidity. F1, F2, F3 and F4 represents Fuzzy model 1 for rainfall input, Fuzzy model 2 for Maximum temperature input, Fuzzy model 3 for minimum temperature input, Fuzzy model 4 for relative humidity input. Results shows that RMSE is high for Fuzzy approach

Table 2: Results of all Fuzzy models

Models	Input	Output	RMSE
F1	RF	WC	81.46
F2	T-MAX	WC	62.77
F3	T-MIN	WC	49.79
F4	RH	WC	54.39

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a. Fuzzy Wavelet Denoised (FWD)

Denoised wavelet is the technique which reduces the unwanted signal which contains less information, these are referred as Noise. By removing noise, only the coefficient which contains more information with respect to time-frequency domain will be retained. This performance is done for different types of wavelets such as Haar (db1), Daubechies of different level such db2, db3, db4, db5, db6 and Other wavelets. The obtained coefficient which contains the information is saved and corresponding statistical properties were obtained and applied to Fuzzy Logic method with optimum number of rules, membership function and fuzzy set. The results obtained reveals that denoised signal have less error compare to Single Fuzzy model. From the Results of the entire Denoised model it shows that, compare to Haar wavelet, Daubechies performed better. In the Daubechies family, db 2 Model performance is better for individual variables analysis. Comparison of Single Fuzzy model, and Fuzzy Wavelet Denoised model is in the table 3.Results of Fuzzy wavelet denoised model for the level 1, level 2, level 3 is represented in the table 4. Results of Fuzzy wavelet Denoised model for the level 4, level 5, level are in the table 5. Here db2 model's better performances in the form of RMSE are RF=7.28, Tmax=8.83 and Tmin=7.74 for level-4, and RH=4.82 for level 2. Decomposition levels of all the climatic variables are shown in the figure 3, figure4, figure5, and figure 6.

Table 3: Comparative Results of single Fuzzy and Fuzzy Wavelet Denoiosed models

Input	Methods In terms of RMSE	
	FL	**FWD**
RF	44.17	7.28
Tmax	21.44	8.83
Tmin	13.04	7.74
RH	13.13	4.82

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a1: approximation, d1,d2,d3 and d4: Detail

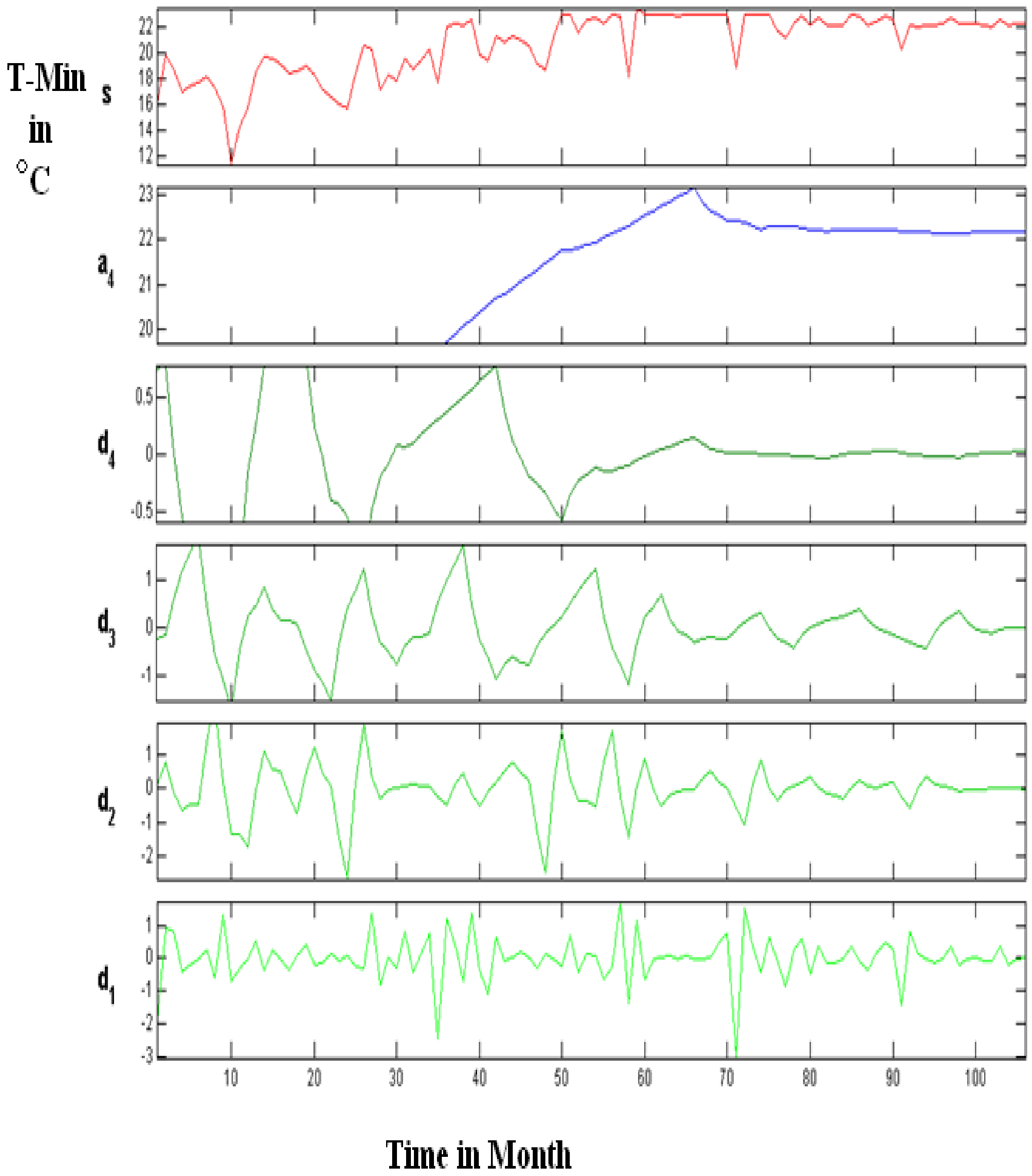

Figure 3Decomposition level of Rainfall data

a1: approximation, d1,d2,d3 and d4: Detail

Figure 4 Decomposition level of Minimum temperature data

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a1: approximation, d1,d2,d3 and d4: Detail

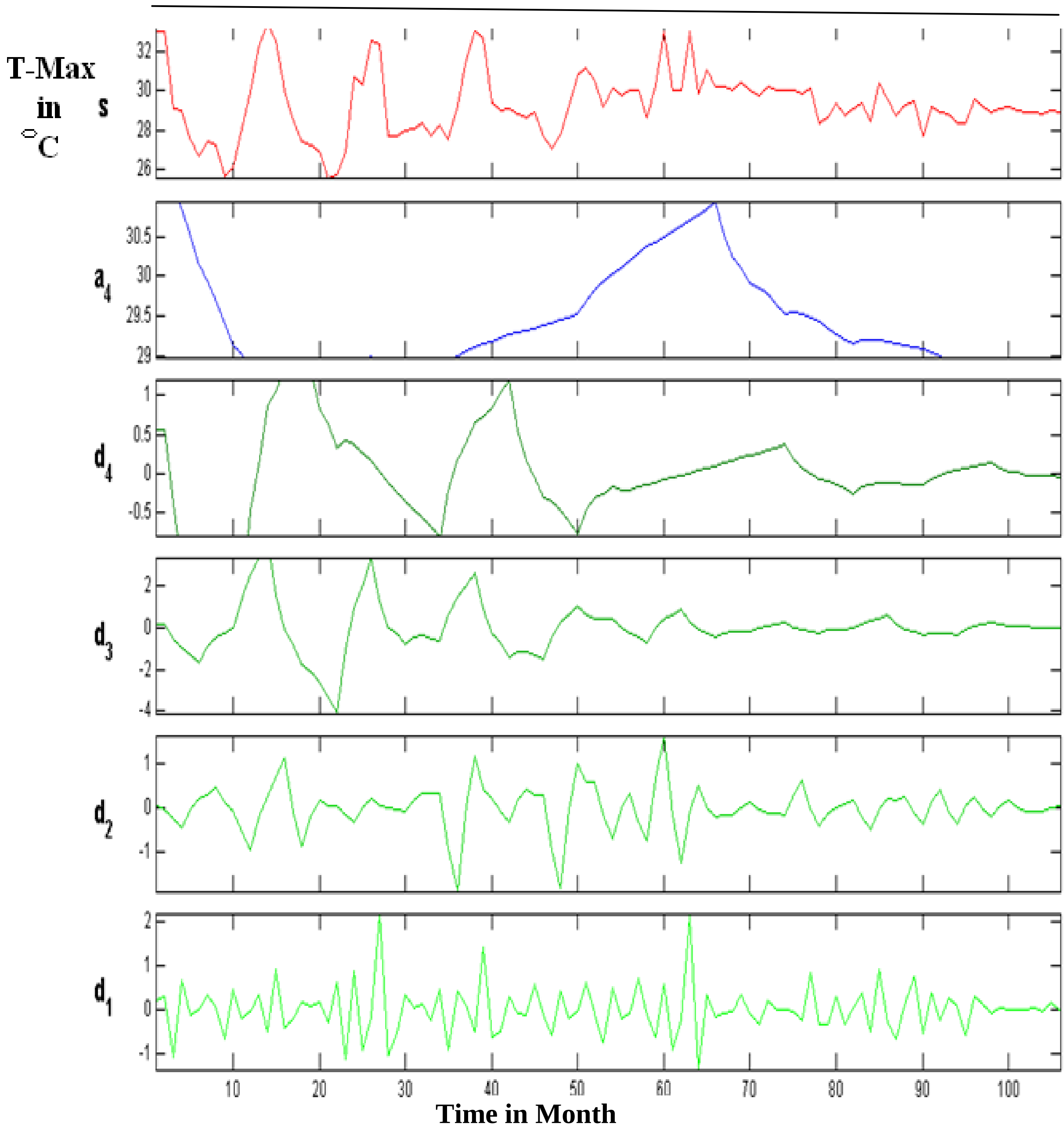

Figure 5 Decomposition level information for maximum temperatuire data

a1: approximation, d1,d2,d3 and d4: Detail

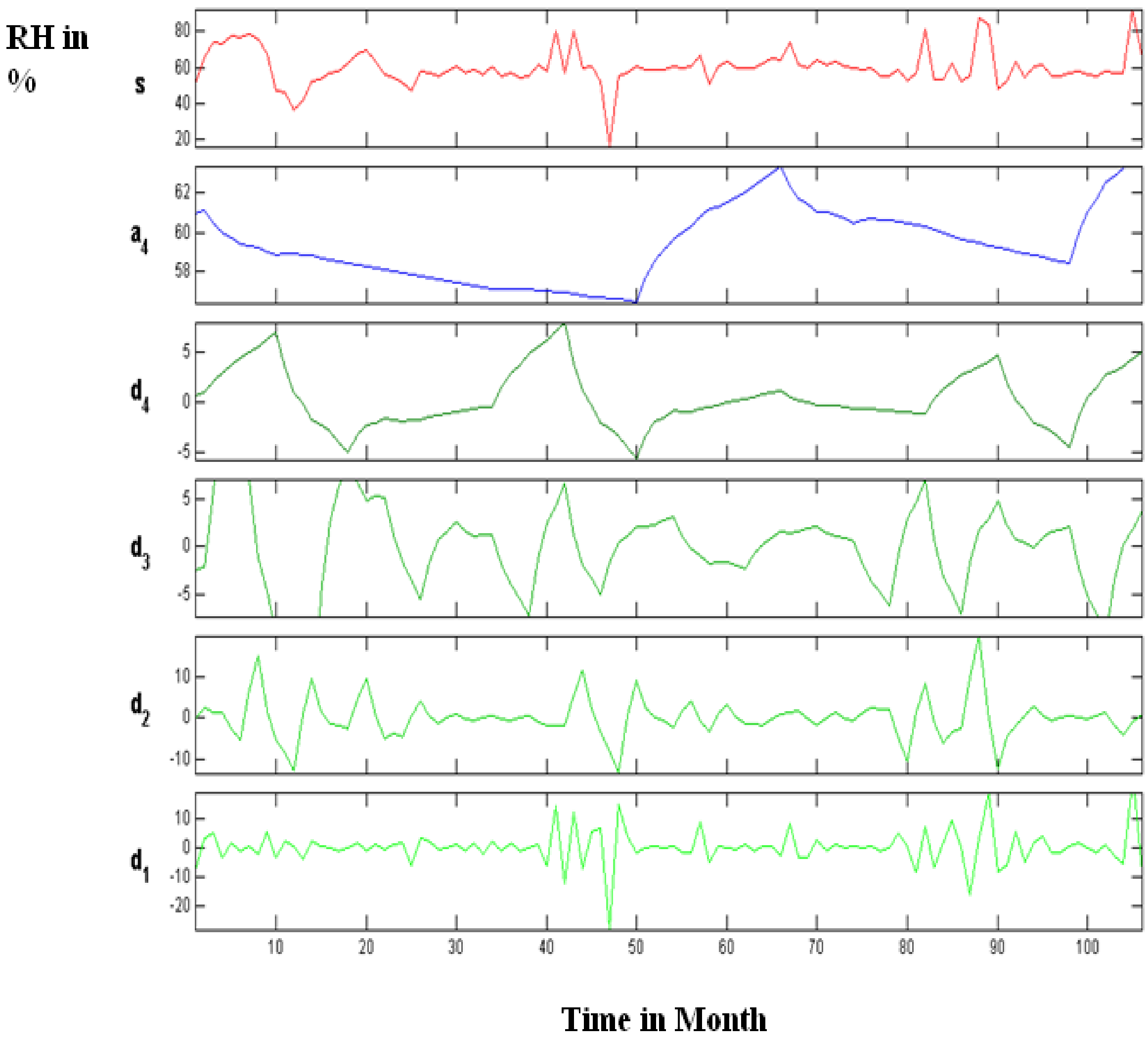

Figure 6 Decomposition level information for Relative humidity data

V. CONCLUSIONS

a) In the present research work, temperature and rainfall are most influencing parameters, as which reduces the error in the analysis by 10 to 20%.

b) Fuzzy-Wavelet Approach such as, Wavelet Denoised has performed better compared to single Fuzzy model approach in modeling water consumption.

c) Among different Wavelets groups, Daubechies wavelet of second group (db2) of level 4, performed better compared to Haarwavelet and all other Daubechies group.

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