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ASSESSMENT OF DROUGHT - USING NONLINEAR AGGREGATED DROUGHT INDEX IN ARTIFIICAL NEURAL NETWORK

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Abstract:

Drought, is caused by the absence of rain is a natural phenomenon. This has its hazardous impacts on human life, industries, environment, and community in general. Understanding drought is thus a very important process considering the present erratic rainfall scenario. It is observed that Maharashtra state has been suffering from lack of rainfall for over two decades, thus drought assessment has become a serious concern in the area. Whenever a drought event and resultant disaster occur, governments and donors follow impact assessments, and response, recovery and reconstruction activities, to return the region or locality to a pre-disaster state. Therefore, it is well recognized that preparedness for drought is the key to the effective mitigation of drought impacts which is becoming more important for water resources managers to handle the challenges in water resources management. To reduce such after event recovery, it is very essential that drought is characterized at the very initial stages and all the required measures are taken beforehand to supply proper water to all the people. There are many methods with which one can assess drought. In this paper, we aim to develop drought forecasting tools by using software's such as SPSS and ANN. The project aims to focus at Manjhara river basin of Latur District in Maharashtra. A new drought index called Nonlinear Aggregated Drought Index (NADI) was established and a time series NADI time series was created using SPSS (Statistical Package for Social Science) software. In order to develop NADI time series the raw data was converted into a series of transformed variables in order to generate Principal components of various months. This data was then put in ANN software and assessment was done.Using this time series, forecast up to 6 months of lead time is possible.

Keywords: -*drought, drought assessment, drought index, artificial neural network, SPSS, Nonlinear aggregated drought index; Manjhara river basin, Latur, Maharashtra*

Introduction:-Drought is a natural phenomenon, indicating lack of rainfall. A region can be said to drought prone if it persistently receives little or no rainfall to meet the demands of people in general. The consequences of drought affected areas are well known to us. Whenever a drought event and resultant disaster occur, governments and donors follow impact assessments, and response, recovery and reconstruction activities, to return the region or locality to a pre-disaster state. Thus, it is of prime importance that we plan our water resources in such a way that water is available to the end user in all seasons regardless of the spatial and temporal variations in rainfall.

This study aims at forming a model that will enable us to assess drought using certain soft computation techniques and development of drought indices. Drought indices or drought index is a numerical value expressed as a function of hydro meteorological parameters like rainfall, streamflow, evapotranspiration etc. it helps in formulating raw data to certain values so as to assist in decision making. With drought indices one can predict different climatic events likely to occur in a particular region, giving us an indication of climatic dryness prevailing in the area due to lack of precipitation. We can also predict that whether the climatic dryness is due to agricultural impacts like loss in moisture of soil or due to lower reservoir levels adding to hydrological impacts of drought. Also, drought indices can be classified based upon the type of technology used to evaluate it. The main objective of this study was to develop a drought assessment model using a soft computing tool with the help of a nonlinear aggregated drought index. Calculating nonlinear aggregates drought index (NADI) for Takli rain gauge station for Manjhara river basin, Latur, Maharashtra is one of the major objectives of this paper. Putting this NADI time series in ANN to assess drought was the second major objective of this paper. As soft computing tools provide easy and hands on reliable solutions compared to hard computing techniques, working on one or more soft computing methods is also an objective of the present work.

Study Area:-

The area under consideration is the Takli rain gauge station of Manjhara river basin of Latur district of Maharashtra. The idea behind selection of this station is the drought history of Latur district. Latur has been observing drought for more than two decades and thus proper drought assessment is of utmost importance to have a stable lifestyle in the district. Long term hydro-meteorological data (36years) for Takli station in the basin was thus collect to commence calculation of NADI.

The Godavari River is 1465km long and is one of the longest flowing rivers in India. The drainage basin of the river is present in six states of India: Chhattisgarh, Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka, and Orissa.

For our study we have taken the Manjara tributary of the Godavari river. The Manjara River is one of the major tributaries of Godavari, which originates in the Balaghat Range of hills in the Beed district of Maharashtra at an altitude of about 823 m. The river flows in a general east and south easterly direction for 512 km covering areas of Maharashtra, some parts of Mysore and Andhra Pradesh. The river then changes its direction and flows for 75km in Northward direction and enters Andhra Pradesh. In Nizamabad district of Andhra Pradesh it flows down for more 102 km and forms a boundary between Maharashtra and Andhra Pradesh. The total length of the river from the source to its confluence with the Godavari at an altitude of 323 m is about 724 km. The catchment area of the Manjara River including its tributaries is 30,844 km2 lying in a zone which gets about 725 mm of rain annually.

Entire latur district receives its major portion of drinking water from Manjara River. Due to improper implementation of water management strategies, the entire city ran out of water in the drought during 2010.

The temperatures in the district vary a lot temporally. The annual temperature is in range of 13°C to 41°C. Talking about rainfall, the annual rainfall in this district is 725mm. monthly rainfall may vary from 9.0 to 693mm/month. The district also experienced severe earthquake of magnitude 6.5 of Richter scale in the year of 1993 which caused life of more than 10,000 people and left more than 30,000 people injured.

NADI time series formation:-

The process of formation of a NADI time series starts with selecting the area for study and obtaining long hydro meteorological data (in this case 36 years data of rainfall and streamflow). Next, the data is segregated month wise for computation of principal components (PC's) (here we have taken data from the month of May to October to Takli). Then using SPSS, the PC's are computed and NADI value is formed by dividing the PC with standard deviation. The NADI values are then rearranged in ascending chronology to form a NADI time series. Based upon the NADI values, drought thresholds are determined for drought classification.

In order to calculate principal components, SPSS software was used. Using this software, we could solve nonlinear principal component analysis and arrive at PC's (Principal Components) for each month (from May1976 to October 2011). The Nonlinear Aggregated Drought Indices (NADI) were calculated thereafter using the formulae

$$NADI_{a,b} = Y_{a1,b} / \sigma$$

Where, $NADI_{a,b}$ is the NADI value in year a for month b ; Y_{a1b} is the principal component PC1 derived from

SPSS for month b in the year a and σ is the standard deviation for all years.

$$\text{So, } NADI_{1976,\ May} = PC1_{1976,\ May} / \sigma$$

means NADI for the month of May in 1976 is equal to PC1(derived by SPSS) of May,1976 divided by σ the standard deviation for all years.

From SPSS, only PC1 is taken into account as it represents maximum variance. Once computation of NADI series for different months is done, it is rearranged into a single NADI time series in ascending order to form a NADI time series as shown in sample calculation below.

Sample Calculation

Let's consider an example to calculate NADI series for the month of May for Takli rain gauge station. The 36 years of rainfall(R) and Stream flow (Q) is arranged in a way to form (36x2) matrix. Let's say this matrix is H. this matrix H is then converted into transformed variable matrix Q using optimal transformation of variables. The Q matrix (36x2) is then used in CATPCA module of SPSS to generate correlation matrix and eigen vector matrix (2x2) using the first PC (PC1)

The relationship between PC and the raw data is established by the equation

$$Y = Q.E$$

Where, Y= (A x B) matrix in which A=number of observation and B= number of variables

H = the transformed matrix (A x B) and E is the eigen vector matrix (B x B) formulated by PC1 of component loadings in CATPCA module of SPSS software.

The NADI value is the obtained by dividing this Y by its standard deviation

$$NADI = Y / \sigma$$

The NADI values for all months are calculated in similar manner and rearranged in asceding order to form a single NADI time series.

Based on the above explanation, H, Q and Ematrix for May are as shown below

$H_{MAY}=$

5.04	0.00
5.56	0.00
24.19	0.00
41.21	0.00
3.68	0.00
9.93	0.00
25.39	0.00
5.23	0.00
0.00	0.00
24.53	0.00
22.40	0.00
18.60	0.00
3.60	0.00
57.60	0.00
168.40	14.02
42.20	2.13
20.20	2.28
34.00	0.00
40.00	1.94
18.40	1.23
4.60	0.00
4.40	12.85
18.90	0.00
122.10	0.00
81.00	0.00
32.60	0.00
48.60	0.00
0.00	0.00
0.00	0.00
0.00	0.00
98.40	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.14

$Q_{MAY}=$

-0.5885	-0.72222
-0.57471	-0.72222
-0.08094	-0.72222
0.37014	-0.72222
-0.62479	-0.72222
-0.45911	-0.72222
-0.04914	-0.72222
-0.58359	-0.72222
-0.72222	-0.72222
-0.07189	-0.72222
-0.12839	-0.72222
-0.22913	-0.72222
-0.62679	-0.72222
0.804767	-0.72222
3.742105	-0.35066
0.396509	-0.66569
-0.18672	-0.66185
0.179125	-0.72222
0.338186	-0.67073
-0.23444	-0.68971
-0.60028	-0.72222
-0.60558	-0.38155
-0.22118	-0.72222

2.51468	-0.72222
1.425107	-0.72222
0.14201	-0.72222
0.566175	-0.72222
-0.72222	-0.72222
-0.72222	-0.72222
-0.72222	-0.72222
1.886386	-0.72222
-0.72222	-0.72222
-0.72222	-0.72222
-0.72222	-0.72222
-0.72222	-0.72222
-0.72222	-0.71845

E_{MAY}=

0.79
0.792

Y_{MAY}=

-1.0369194
-1.02602081
-0.63594609
-0.27959154
-1.06558314
-0.93469494
-0.61082241
-1.03303983
-1.1425592
-0.62879269
-0.67343344
-0.75301728
-1.06716399
0.063764183
2.67853972
-0.2139864
-0.67169157
-0.43049332
-0.26404886
-0.73145412
-1.04622088
-0.78059201
-0.74673434
1.414595058
0.553833058
-0.45981368
-0.12472385
-1.1425592
-1.1425592
-1.1425592
0.918243248
-1.1425592
-1.1425592

-1.1425592
-1.1425592
-1.13957182

The NADI value is then obtained by dividing this Y by its standard deviation, NADI = Y / σ as is as below

Putting NADI series into ANN:-

AS stated earlier in order to assess the drought conditions ANN was used. The first step here is selection of appropriate input parameters for the software tool. The second step involves model development and calibration of hidden neurons. Finally the model is complete by investigating some model performances to understand how the software works.

$NADI_{MAY}$=

-1.265465611
-1.252164883
-0.776114234
-0.341215988
-1.300447097
-1.140709985
-0.745453083
-1.26073095
-1.394389368
-0.767384161
-0.821864135
-0.918988951
-1.302376384
0.077818373
3.268913588
-0.2611509
-0.819738339
-0.525377854
-0.322247568
-0.892673083
-1.276817222
-0.952641404
-0.911321203
1.726384333
0.675902768
-0.561160681
-0.152214086
-1.394389368
-1.394389368
-1.394389368
1.120632189
-1.394389368

-1.394389368
-1.394389368
-1.394389368
-1.390743537

Likewise, NADI for other months can be calculated and arranged in chronological order to form a NADI time series as below

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In order to forecast NADI value several lead months ahead, NADI values of all previous months are put as input and ANN with back propagation is used

On the same theory a sample value calculation for the month of May is as shown

Result:-Here, using ANN it can said that after 3 iterations, the value of R is 0.96 and MSE is 0.08 which is favorable and satisfies the basic requirement of ANN. Likewise, all other stations and respective months / years can be worked out.The Mat lab ANN software was used to compute all the values for assessment of drought.

NADI TIME SERIES FOR TAKLI RAINGAUGE STATION

	MAY	JUNE	JULY	AUG	SEPT	OCT
1976	-1.26547	-0.10352	0.39641	-0.05914	-0.89009	-0.82636
1977	-1.25216	-0.12406	-0.34289	-0.57757	-1.06618	-0.35515
1978	-0.77611	2.039467	0.369546	-0.6962	-0.63108	-0.10073
1979	-0.34122	-0.2584	-0.73204	-0.86655	0.570207	-0.78144
1980	-1.30045	2.002305	-0.86351	0.127519	-0.31019	-0.77916
1981	-1.14071	0.110438	-0.58988	-0.87218	0.759276	0.265253
1982	-0.74545	0.119174	-0.4201	-1.08461	-0.11685	-0.68129
1983	-1.26073	-0.54377	1.003409	1.645819	2.275529	2.762399
1984	-1.39439	-0.9651	0.030498	-1.14772	-0.41541	-0.06138
1985	-0.76738	-0.07893	-0.39471	-1.0902	-0.61743	-0.07232
1986	-0.82186	-1.05976	-0.96499	-0.31637	-0.95743	-0.84321
1987	-0.91899	0.253428	-0.17902	0.085481	-1.08281	0.473777
1988	-1.30238	0.526794	0.280307	1.157639	3.140828	-0.47587
1989	0.077818	0.453193	3.274259	0.278186	0.672168	-0.44058
1990	3.268914	3.167871	-0.29105	2.142127	-0.21874	2.490472
1991	-0.26115	0.43292	1.951891	-0.83103	-0.92826	-0.86178
1992	-0.81974	0.328782	-0.92148	-0.03388	-0.11697	-0.37578
1993	-0.52538	-0.99833	-0.49975	-0.39856	-0.71699	-0.07606
1994	-0.32225	0.13889	-0.71323	-0.86784	-1.01856	0.079264
1995	-0.89267	0.865404	0.521247	-0.69215	-0.78946	0.512115
1996	-1.27682	-1.14469	0.559946	0.389932	1.396665	0.523833
1997	-0.95264	-0.35054	-0.28616	-0.73977	-0.38529	-0.22333
1998	-0.91132	-0.39993	1.285789	0.617462	1.581761	3.057439
1999	1.726384	0.240992	-0.79451	0.101184	-0.16421	1.609684
2000	0.675903	0.259124	-0.61606	2.803391	-0.61129	-0.73832
2001	-0.56116	0.186331	-1.10551	-0.09825	0.655427	-0.45301
2002	-0.15221	-0.2254	-0.7587	-0.322	-0.76308	-0.44615
2003	-1.39439	-1.52083	-0.16086	-0.13199	-0.92462	-0.78439
2004	-1.39439	-0.70892	0.207071	-0.92523	-0.61425	-0.45162
2005	-1.39439	-1.52083	0.680178	-0.5999	0.315425	0.684772
2006	1.120632	0.417274	-0.76382	0.191563	0.665868	0.029379

2007	-1.39439	1.392368	-0.83656	-0.75667	0.589299	-0.80353
2008	-1.39439	-0.90233	-0.72631	-0.14997	1.323633	-0.59806
2009	-1.39439	-0.15089	-0.93382	0.156488	-0.46861	-0.32663
2010	-1.39439	-0.75727	2.14265	2.400965	0.323622	-0.35252
2011	-1.39074	-1.12126	1.191778	1.160026	-0.46192	-0.57975

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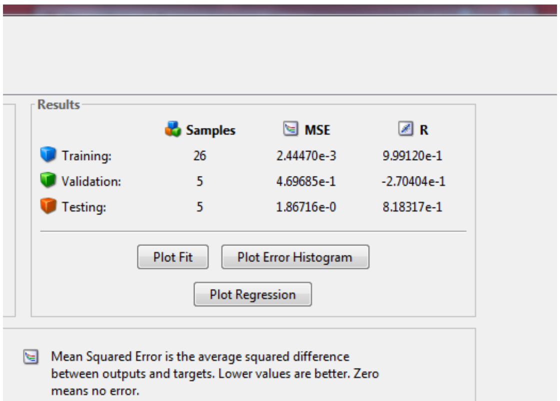
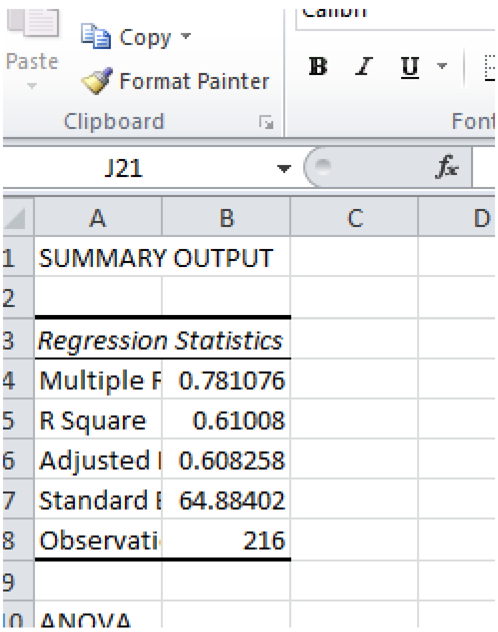


Results

	Samples	MSE	R
Training:	26	2.44470e-3	9.99120e-1
Validation:	5	4.69685e-1	-2.70404e-1
Testing:	5	1.86716e-0	8.18317e-1

The same values of input and output data was put in excel to form a regression. The output obtained by MS-Excel is as follows



	A	B
1	SUMMARY OUTPUT	
2		
3	*Regression Statistics*	
4	Multiple F	0.781076
5	R Square	0.61008
6	Adjusted I	0.608258
7	Standard E	64.88402
8	Observati	216
9		
10	ANOVA	

In Excel, it can be seen that the value for R is equal to 0.79 and MSE is 0.62. both these values are notfavourable.The ideal range of R is between 0 to 1 where 1 indicates excellent forecasting while 0 indicates poor forecasting. On the other hand, the range for MSE is also between 0 to 1 where 0 indicates best fit while 1 indicates poor performance of the model. In short, large R value (close to 1) and low MSE values (as good as zero) indicate a good model. So, comparing both ANN and Excel it is clear that for this particular station, the output achieved by ANN is more superior and should be taken into consideration. The forecast values achieved by ANN will be more precise and accurate.

Conclusion:-Thus we can conclude that in order to provide water to user even during dry season, proper assessment of drought is necessary. This will not only help us to take precautionary measures at the initial stage, but will also help us predict and understand the behaviour of changes in drought patterns. Many tools are available to assess a given situation for dry period. We can classify drought as per hydrological drought, agricultural drought and metrological drought, depending upon the type of drought, drought assessment can be done. Drought assessment helps us in both past and future; we can understand and study the drought patterns in retrospect of a given region and we can also study the prospective behaviour of rainfall / drought pattern.

The main objective of this study was to develop a drought assessment model using a soft computing tool with the help of a nonlinear aggregated drought index. Calculating nonlinear aggregates drought index (NADI) for Takli rain gauge station for Manjhara river basin, Latur, Maharashtra and TO put this NADI time series in ANN to assess drought.

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