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Correlation between Standardized Precipitation Index and Standardized Runoff Index: A Case Study of AJI Basin

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Abstract: ***Drought is a global catastrophe. One can simply defined it as a continued, extended scarcity in precipitation. The amount of damages due to drought depends upon its intensity and length of time of occurrence. Incidence of drought is not certain so it is very essential to detect, monitor and assess drought. For that drought index is very useful tool. In present study standardized precipitation index (SPI) and standardized runoff index (SRI) i.e. indicator of meteorological drought and hydrological drought respectively is correlated to more or less predict hydrological drought from meteorological drought. Aji basin covering part of Rajkot and Jamnagar district of Saurastra, Gujarat is considered as a study area. SPI, SRI and their correlation is worked out for five reservoir Aji1, Aji2, Aji3, Lalpari reservoir and Nyari2 of Aji basin at interval of 15 days starting from 1st June and upto 1st October. To obtain SPI and SRI, 12 years (2005-06 to 2016-17) precipitation and runoff data are used. By observing coefficient of correlation between SPI and SRI it is concluded that after 60 days there is strong relationship between them. So after 60 days hydrological drought can be predicted based on meteorological drought.***
Keywords: Drought, drought index, standardized precipitation index, standardized runoff index, coefficient of correlation.

I. INTRODUCTION

There is no standard and commonly undertaken definition of drought but generally it is defined as extended period of days, months or years when a region notes a deficiency in water availability. It is very clear that drought cannot be seen merely as a event but have a great impact on the environment and society of influenced area. So it is essential to examine, monitor and evaluate drought.

Droughts have been generally classified into four types like meteorological drought; deficiency of precipitation extended over some time, hydrological drought; deficiency in water supplies leading to lake of water, agricultural drought; deficiency of soil moisture content and socioeconomic drought; it is associate supply and demand of economic good. Drought have various worst impacts like economic, social and environmental.

Prolonged and regionally widespread incidence of below average natural water availability is known as hydrological drought. Hydrological drought is defined as decrease of available water in all its forms. *(Abhishek A. Pathak, 2016 [3]).* Hydrological drought is nothing but enxtended meteorological drought. So considering worst impacts of drought it is very essential to more or less predict hydrological drought from meteorological drought. And hence meteorological drought and hydrological drought are correlated using Karl Pearson's coefficient of correlation in present study.

A. Necessity for study

Drought analysis is carried out to check, to examine, to assess and also to predict drought episode. Such analysis is very useful to moderate or downgrade drought impacts owing to attentiveness and drought mitigation. As hydrological drought is extended meteorological drought so as to analyze or to characterize drought it is very essential to predict meteorological drought and correlate it to hydrological drought. For this purpose study is carried out.

B. Study Area

Aji basin of Rajkot district of Gujarat, India is selected as a study area. Aji tributaries start off from Sardhara ridge of Rajkot district, stream in northwest direction for a length of 102km, drain off 2130km^2 catchment area and terminate in little rann of Kucchchh. From Aji basin Aji1, Aji2, Aji3, Lalpari reservoir and Nyari2 dams are considered in analysis.

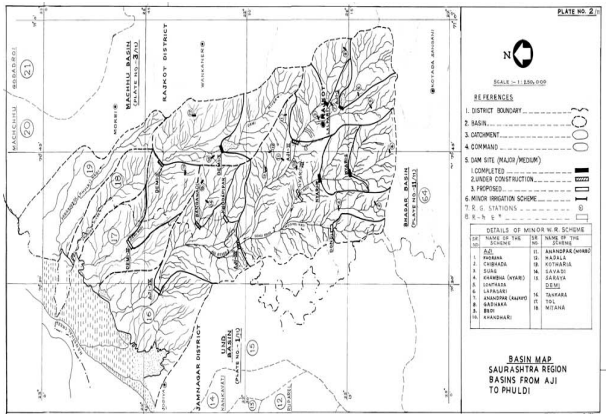

Figure 1. Aji basin

II. METHODOLOGY

SPI is calculated by using very simple formula as per following.

$$SPI = \frac{x_i - \bar{x}}{\sigma} \quad (1)$$

where, x_i = measured single precipitation
$\bar{x}$ = average of historical precipitation
σ = standard deviation of historical precipitation

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n}} \quad (2)$$

Similarly SRI is calculated by using runoff instead of precipitation in SPI (equation 1). Following table shows description of class of drought with aid of standardized index applicable for both SPI and SRI.

Table 1. Description of class of drought with the aid of standardized index applicable for both SPI and SRI

Drought Categories	Value of Standardized Index
Extremely wet	+ 2 to more
Very wet	1.5 to 1.99
Moderately wet	1.0 to 1.49
Near normal	-0.99 to 0.99
Moderately dry	-1.0 to -1.49
Severely dry	-1.5 to -1.99
Extremely dry	-2 to less

After calculating SPI and SRI, they are correlated by coefficient of correlation to correlate hydrological drought with meteorological drought. In this study Karl Pearson's coefficient of correlation is used to correlate SRI with SPI.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 * \sum(y_i - \bar{y})^2}} \quad (3)$$

Interpretation of coefficient of correlation is shown in table below.

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Table 2. Interpretation of coefficient of correlation

Value of coefficient of correlation	Relationship
0 – 0.3	Weak relationship
0.3 – 0.7	Moderate relationship
0.7 – 1	Strong relationship

III. RESULT AND ANALYSIS

SPI and SIR have been calculated using equation(1). To calculate standardized indices interval of 15 days has been selected starting from 1st of June to 1st of October. Hence drought indices have been worked out for 15 days (1st June to 16th June - SPI15/SRI15), 30 days (1st June to 1st July – SPI30/SRI30), 45 days (1st June to 16th July – SPI45/SRI45), 60 days (1st June to 1st Aug – SPI60/SRI60), 75 days (1st June to 16th Aug – SPI75/SRI75), 90 days (1st June to 1st Sept – SPI90/SRI90), 105 days (1st June to 16th Sept – SPI105/SRI105) and 120 days (1st June to 1st Oct – SPI120/SRI120) from 2005-06 to 2016-17.

A. SPI

Following tables represents calculated SPI for Aji1 dam, Aji2 dam, Aji3 dam, Lalpari reservoir and Nyari2 dam.

Table 3. SPI of Aji1 dam

Year	SPI15	SPI30	SPI45	SPI60	SPI75	SPI90	SPI105	SPI120
2005/06	-0.752	1.916	1.183	1.004	0.375	0.133	0.385	0.569
2006/07	0.913	0.202	0.305	0.967	0.117	0.081	-0.214	-0.329
2007/08	-0.569	-0.148	1.661	0.998	2.128	1.879	1.434	1.646
2008/09	2.615	0.709	-0.004	-0.553	0.031	-0.205	0.193	0.453
2009/10	-0.752	-0.793	-0.836	1.028	-0.025	0.278	-0.055	-0.386
2010/11	-0.386	-0.793	-0.050	0.499	0.883	1.296	1.913	1.370
2011/12	-0.752	-0.581	0.806	0.146	0.835	1.037	1.042	0.708
2012/13	-0.203	-0.720	**-1.237**	**-1.739**	**-1.725**	**-1.741**	**-1.128**	**-1.194**
2013/14	0.804	0.156	0.189	-0.176	-0.182	-0.261	-0.494	0.586
2014/15	-0.752	-0.904	**-1.546**	**-1.526**	**-1.437**	**-1.241**	**-1.307**	**-1.490**
2015/16	0.584	1.953	0.844	0.633	-0.137	-0.361	-0.591	-0.604
2016/17	-0.752	-0.996	**-1.314**	**-1.283**	-0.865	-0.895	**-1.177**	**-1.331**

Table 4. SPI of Aji2 dam

Year	SPI15	SPI30	SPI45	SPI60	SPI75	SPI90	SPI105	SPI120
2005/06	-0.765	1.671	0.988	0.678	0.371	0.292	0.461	0.670
2006/07	-0.765	-0.642	-0.530	1.468	0.782	0.725	0.437	0.301
2007/08	-0.765	0.480	2.062	1.160	2.105	1.724	1.697	1.436
2008/09	1.979	-0.006	-0.752	**-1.085**	-0.510	-0.714	-0.358	-0.111
2009/10	-0.765	-0.989	-0.308	0.320	-0.271	0.080	-0.248	-0.542
2010/11	0.547	-0.203	1.136	0.930	1.028	1.666	1.880	1.280
2011/12	-0.734	**-1.035**	-0.004	0.376	0.273	0.248	0.534	0.131
2012/13	-0.612	-0.989	**-1.397**	**-1.825**	**-1.770**	**-1.795**	**-1.400**	**-1.515**
2013/14	1.370	0.746	0.062	-0.033	0.113	-0.100	-0.375	1.351
2014/15	-0.765	**-1.047**	**-1.567**	**-1.405**	**-1.390**	**-1.140**	**-1.327**	**-1.458**
2015/16	1.431	1.960	0.359	0.079	-0.439	-0.646	-0.692	-0.720
2016/17	-0.155	0.052	-0.049	-0.666	-0.294	-0.339	-0.609	-0.820

Table 5. SPI of Aji3 dam

Year	SPI15	SPI30	SPI45	SPI60	SPI75	SPI90	SPI105	SPI120
2005/06	-0.585	0.712	-0.006	-0.186	-0.166	-0.384	-0.218	-0.059
2006/07	-0.585	-0.132	-0.156	0.261	0.240	0.139	-0.207	-0.215
2007/08	0.007	0.562	3.062	2.188	2.640	2.331	2.204	2.142
2008/09	3.028	1.124	-0.307	-0.627	-0.384	-0.589	-0.525	-0.160
2009/10	-0.585	-0.506	0.325	0.417	-0.132	0.231	-0.141	-0.475
2010/11	0.007	-0.787	-0.259	-0.102	0.497	0.963	1.788	1.659
2011/12	-0.585	**-1.162**	-0.006	1.434	0.852	0.976	0.827	0.658
2012/13	-0.437	-0.881	-0.938	**-1.611**	**-1.685**	**-1.780**	-0.868	**-1.153**
2013/14	0.156	0.169	-0.066	-0.577	-0.615	-0.674	-0.945	0.311
2014/15	-0.585	-0.506	-0.788	-0.387	-0.512	-0.465	-0.572	-0.935
2015/16	0.748	2.379	0.048	0.328	-0.200	-0.384	-0.664	-0.721
2016/17	-0.585	-0.975	-0.908	**-1.136**	-0.534	-0.364	-0.682	**-1.052**

Table 6. SPI of Lalpari reservoir

Year	SPI15	SPI30	SPI45	SPI60	SPI75	SPI90	SPI105	SPI120
2005/06	-0.746	1.979	1.376	1.072	0.604	0.304	0.403	0.510
2006/07	-0.746	-0.154	-0.169	0.953	0.105	0.089	-0.248	-0.302
2007/08	-0.613	-0.393	1.965	0.834	1.482	1.165	1.170	1.209
2008/09	2.748	0.819	-0.022	-0.677	-0.039	-0.288	-0.147	0.169
2009/10	-0.746	**-1.039**	**-1.051**	0.805	-0.117	0.124	-0.263	-0.572
2010/11	-0.247	-0.464	-0.058	1.042	1.521	1.973	2.153	1.821
2011/12	0.169	-0.553	0.457	-0.203	0.932	1.090	1.256	0.952
2012/13	-0.247	-0.641	-0.904	**-1.565**	**-1.678**	**-1.760**	**-1.044**	**-1.099**
2013/14	0.668	0.510	0.310	-0.143	-0.156	-0.324	-0.494	0.624
2014/15	-0.746	**-1.039**	**-1.603**	**-1.506**	**-1.619**	**-1.168**	**-1.189**	**-1.470**
2015/16	1.001	1.793	0.677	0.716	-0.176	-0.414	-0.595	-0.643
2016/17	-0.496	-0.818	-0.978	**-1.328**	-0.858	-0.791	**-1.000**	**-1.199**

Table 7. SPI of Nyari2 dam

Year	SPI15	SPI30	SPI45	SPI60	SPI75	SPI90	SPI105	SPI120
2005/06	-0.593	0.912	0.362	0.120	-0.043	-0.171	-0.023	0.180
2006/07	-0.593	-0.851	-0.763	1.071	0.375	0.210	-0.097	-0.175
2007/08	-0.593	-0.243	1.928	0.934	2.317	1.831	1.848	1.747
2008/09	2.913	1.580	0.607	0.082	-0.482	-0.057	0.163	0.247
2009/10	-0.593	-0.729	-0.323	0.280	-0.373	-0.102	-0.401	-0.638
2010/11	0.438	-0.243	0.314	1.452	1.369	1.984	2.070	1.615
2011/12	-0.593	**-1.094**	0.264	-0.375	0.270	0.325	0.589	0.264
2012/13	-0.284	-0.365	**-1.155**	**-1.860**	**-1.547**	**-1.659**	-0.949	**-1.138**
2013/14	0.851	0.669	0.832	0.120	0.061	-0.190	-0.449	1.007
2014/15	-0.593	**-1.094**	**-1.693**	**-1.167**	**-1.066**	-0.915	**-1.004**	**-1.188**
2015/16	0.232	2.006	0.803	0.805	-0.085	-0.400	-0.630	-0.665
2016/17	-0.593	-0.547	**-1.179**	**-1.464**	-0.795	-0.857	**-1.116**	**-1.256**

B. SRI

Following tables represents calculated SRI for Aji1 dam, Aji2 dam, Aji3 dam, Lalpari reservoir and Nyari2 dam.

Table 8. SRI of Aji1 dam

Year	SRI15	SRI30	SRI45	SRI60	SRI75	SRI90	SRI105	SRI120
2005/06	2.090	1.475	0.553	0.052	-0.121	-0.279	-0.229	-0.245
2006/07	-0.222	-0.477	0.079	-0.032	-0.010	-0.237	-0.387	-0.448
2007/08	-0.325	1.588	0.607	2.958	2.811	2.552	2.519	2.485
2008/09	-0.534	-0.706	**-1.016**	-0.632	-0.660	-0.544	0.024	0.228
2009/10	-0.559	-0.628	0.387	-0.301	-0.252	-0.401	-0.585	-0.642
2010/11	-0.558	-0.175	0.187	0.148	0.444	1.183	1.114	1.055
2011/12	-0.559	0.059	2.301	0.809	1.050	1.084	1.011	0.933
2012/13	-0.559	-0.970	**-1.205**	-0.807	-0.809	-0.776	-0.936	-0.979
2013/14	-0.254	-0.480	-0.730	-0.558	-0.595	-0.670	-0.147	0.119
2014/15	-0.469	-0.769	-0.908	-0.692	-0.718	-0.613	-0.767	-0.809
2015/16	2.346	1.920	0.865	-0.163	-0.330	-0.487	-0.649	-0.685
2016/17	-0.398	-0.837	**-1.119**	-0.783	-0.808	-0.812	-0.969	**-1.012**

Table 9. SRI of Aji2 dam

Year	SRI15	SRI30	SRI45	SRI60	SRI75	SRI90	SRI105	SRI120
2005/06	-0.684	**-1.211**	0.206	-0.210	0.070	-0.036	0.229	0.564
2006/07	-0.522	**-1.117**	0.855	0.135	0.233	0.002	0.036	-0.065
2007/08	-0.219	-0.940	1.765	3.132	2.928	2.680	2.645	2.586
2008/09	0.646	-0.436	-0.873	-0.482	-0.613	-0.654	-0.641	-0.170
2009/10	-0.357	**-1.020**	0.286	-0.370	-0.346	-0.374	-0.453	-0.546
2010/11	-0.465	**-1.084**	0.202	0.349	0.516	1.059	1.017	0.931
2011/12	-0.539	**-1.126**	1.622	0.207	0.558	0.820	0.800	0.725
2012/13	-0.648	**-1.190**	**-1.371**	-0.727	-0.843	-0.779	-0.810	-0.905
2013/14	0.384	-0.589	-0.650	-0.487	-0.601	-0.672	-0.648	-0.670
2014/15	-0.557	**-1.137**	**-1.277**	-0.654	-0.740	-0.741	-0.792	-0.885
2015/16	3.046	0.963	0.049	-0.428	-0.590	-0.663	-0.693	-0.786
2016/17	-0.086	-0.862	-0.813	-0.464	-0.572	-0.640	-0.690	-0.778

Table 10. SRI of Aji3 dam

Year	SRI15	SRI30	SRI45	SRI60	SRI75	SRI90	SRI105	SRI120
2005/06	1.681	0.339	0.228	0.101	0.042	-0.017	0.278	0.259
2006/07	-0.561	-0.529	1.003	0.158	0.209	0.013	-0.138	-0.159
2007/08	-0.317	3.181	2.461	3.147	2.949	2.790	2.590	2.513
2008/09	0.557	-0.239	-0.726	-0.530	-0.625	-0.367	-0.424	-0.444
2009/10	-0.561	-0.206	-0.036	-0.392	-0.304	-0.391	-0.615	-0.633
2010/11	-0.561	-0.339	-0.081	0.226	0.801	1.176	1.041	1.003
2011/12	-0.561	-0.347	0.812	0.027	0.126	0.278	0.184	0.145
2012/13	-0.561	-0.529	-0.991	-0.653	-0.748	-0.741	-0.951	-0.958
2013/14	-0.506	-0.516	-0.978	-0.640	-0.726	-0.798	0.616	0.878
2014/15	-0.561	-0.529	-0.944	-0.633	-0.725	-0.769	-0.972	-0.978
2015/16	2.511	0.237	0.168	-0.343	-0.466	-0.569	-0.786	-0.794
2016/17	-0.561	-0.522	-0.915	-0.470	-0.534	-0.604	-0.823	-0.831

Table 11. SRI of Lalpari reservoir

Year	SRI15	SRI30	SRI45	SRI60	SRI75	SRI90	SRI105	SRI120
2005/06	2.368	1.648	0.978	0.134	-0.039	-0.177	-0.411	-0.410
2006/07	-0.393	-0.261	0.330	-0.001	-0.093	-0.163	-0.398	-0.394
2007/08	-0.468	1.665	0.860	2.533	1.948	1.472	0.999	0.988
2008/09	-0.398	-0.824	**-1.157**	-0.699	-0.722	-0.435	1.696	1.681
2009/10	-0.578	-0.915	0.701	0.004	-0.104	-0.225	-0.472	-0.491
2010/11	-0.567	-0.341	0.560	0.809	1.597	1.696	1.232	1.221
2011/12	-0.567	1.030	1.704	1.007	1.303	1.805	1.414	1.411
2012/13	-0.578	-0.938	**-1.245**	**-1.016**	**-1.028**	-0.959	**-1.076**	**-1.093**
2013/14	0.408	-0.138	-0.594	-0.558	-0.580	-0.636	-0.117	-0.006
2014/15	-0.578	-0.963	**-1.243**	-0.999	-0.926	-0.907	**-1.049**	**-1.052**
2015/16	1.928	0.998	0.358	-0.197	-0.331	-0.441	-0.653	-0.674
2016/17	-0.578	-0.963	**-1.254**	**-1.016**	**-1.026**	**-1.029**	**-1.166**	**-1.182**

Table 12. SRI of Nyari2 dam

Year	SRI15	SRI30	SRI45	SRI60	SRI75	SRI90	SRI105	SRI120
2005/06	-0.521	-0.260	-0.345	-0.144	-0.174	-0.135	0.151	0.176
2006/07	-0.521	-0.442	0.357	-0.153	-0.102	-0.167	-0.236	-0.257
2007/08	-0.151	3.269	3.053	3.227	2.970	2.753	2.532	2.473
2008/09	0.528	-0.303	-0.572	-0.349	-0.455	-0.414	-0.175	-0.144
2009/10	-0.521	-0.425	0.189	-0.254	-0.267	-0.272	-0.511	-0.532
2010/11	0.105	-0.180	0.258	0.325	1.101	1.516	1.378	1.353
2011/12	-0.521	-0.190	-0.067	-0.356	-0.466	-0.519	-0.743	-0.757
2012/13	-0.521	-0.482	-0.885	-0.608	-0.707	-0.683	-0.891	-0.910
2013/14	-0.044	-0.265	-0.575	-0.412	-0.485	-0.531	0.645	0.792
2014/15	-0.471	-0.416	-0.494	-0.481	-0.577	-0.611	-0.819	-0.828
2015/16	3.140	0.152	-0.129	-0.260	-0.341	-0.418	-0.610	-0.633
2016/17	-0.498	-0.458	-0.790	-0.537	-0.496	-0.517	-0.721	-0.733

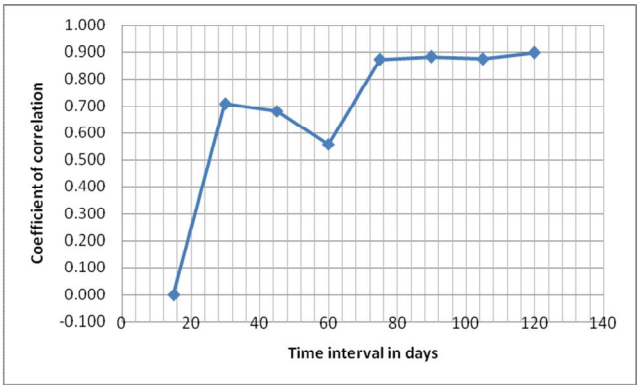
C. Coefficient of Correlation

Coefficient of correlation has been calculated using equation 3. It is as per shown in table below.

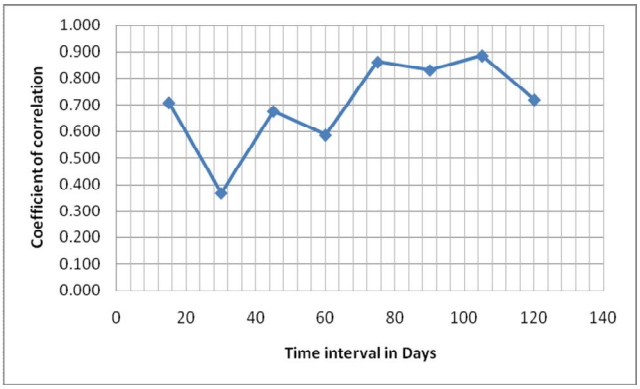
Table 13. Coefficient of correlation between SPI and SRI

Interval / Dam	15	30	45	60	75	90	105	120
Aji1 dam	0.000	0.708	0.681	0.555	0.872	0.882	0.874	0.897
Aji2 dam	0.708	0.368	0.676	0.586	0.862	0.831	0.885	0.719
Aji3 dam	0.365	0.360	0.848	0.765	0.923	0.891	0.823	0.939
Lalpari reservoir	0.105	0.552	0.618	0.646	0.899	0.917	0.782	0.819
Nyari2 dam	0.360	0.036	0.613	0.463	0.888	0.860	0.821	0.904

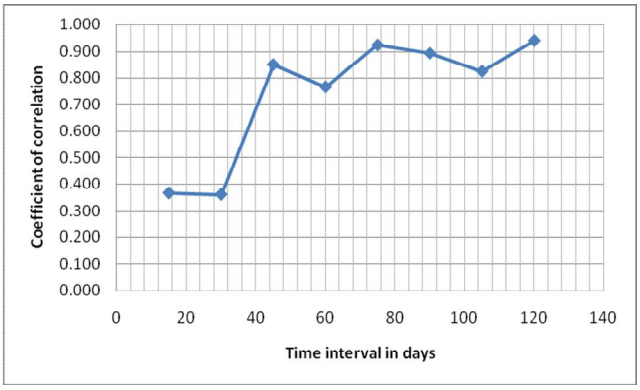
Graph of coefficient of correlation v/s time interval is as per following.



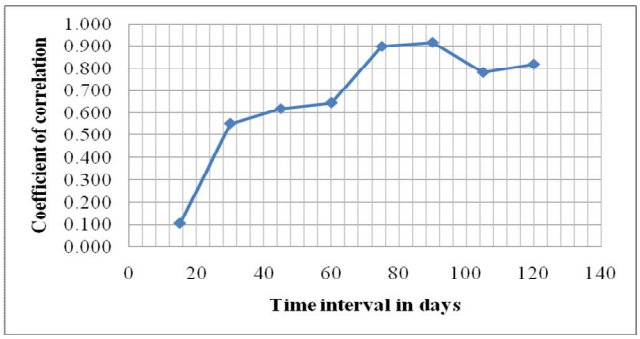
Graph 1. Coefficient of correlation v/s time interval of Aji1 dam



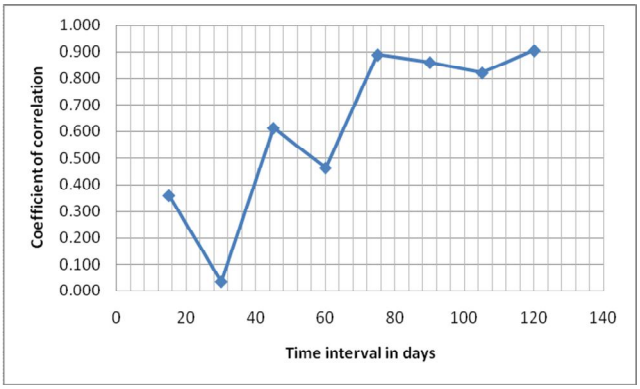
Graph 2. Coefficient of correlation v/s time interval of Aji2 dam



Graph 3. Coefficient of correlation v/s time interval of Aji3 dam



Graph 4. Coefficient of correlation v/s time interval of Lalpari reservoir



Graph 5. Coefficient of correlation v/s time interval of Nyari2 dam

After calculating standardized indices and their interpretation, percentage of years of drought is calculated and it as per given below.

Table 14. Percentage of years of drought based on SPI

	No. of years	Occurrence of drought							
		No.	%	No.	%	No.	%	No.	%
Interval / Dam		75		90		105		120	
Aji1 dam	12	2	16.7	2	16.67	3	25	3	25
Aji2 dam	12	2	16.7	2	16.67	2	16.67	2	16.67
Aji3 dam	12	1	8.33	1	8.33	0	0	2	16.67
Lalpari reservoir	12	2	16.7	2	16.67	3	25	3	25
Nyari2 dam	12	2	16.7	1	8.33	2	16.67	3	25

Table 15. Percentage of years of moderate drought based on SPI

	No. of years	Occurrence of drought							
		No.	%	No.	%	No.	%	No.	%
Interval / Dam		75		90		105		120	
Aji1 dam	12	1	8.33	1	8.33	3	25	3	25
Aji2 dam	12	1	8.33	1	8.33	2	16.67	1	8.33
Aji3 dam	12	0	0	0	0	0	0	2	16.67
Lalpari reservoir	12	0	0	1	8.33	3	25	3	25
Nyari2 dam	12	1	8.33	0	0	2	16.67	3	25

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Table 16. Percentage of years of severe drought based on SPI

	No. of years	Occurrence of drought							
		No.	%	No.	%	No.	%	No.	%
Interval / Dam		75		90		105		120	
Aji1 dam	12	1	8.33	1	8.33	0	0	0	0
Aji2 dam	12	1	8.33	1	8.33	0	0	1	8.33
Aji3 dam	12	1	8.33	1	8.33	0	0	0	0
Lalpari reservoir	12	2	16.67	1	8.33	0	0	0	0
Nyari2 dam	12	1	8.33	1	8.33	0	0	0	0

Table 17. Percentage of years of drought based on SRI

	No. of years	Occurrence of drought							
		No.	%	No.	%	No.	%	No.	%
Interval / Dam		75		90		105		120	
Aji1 dam	12	1	8.33	0	0	0	0	1	8.33
Aji2 dam	12	0	0	0	0	0	0	0	0
Aji3 dam	12	0	0	0	0	0	0	0	0
Lalpari reservoir	12	2	16.67	1	8.33	3	25	3	25
Nyari2 dam	12	0	0	0	0	0	0	0	0

IV. CONCLUSION

Coefficient of correlation between standardized precipitation index and standardized runoff index has been calculated. And its interpretation has been done (Table 25 & 26). It has been found that there is strong relationship between SPI and SRI after 60 days. It is matter of investigation that why correlation between SPI and SRI is not strong for upto 60 days. Also occurrence of drought as per SPI is verified with actual drought occurrence and it is as per given in table below.

Table 18. Validation table

Dam	Aji1 dam	Aji2 dam	Aji3 dam	Lalpari reservoir	Nyari2 dam
Percentage of match	91.67	83.33	100	91.67	91.67

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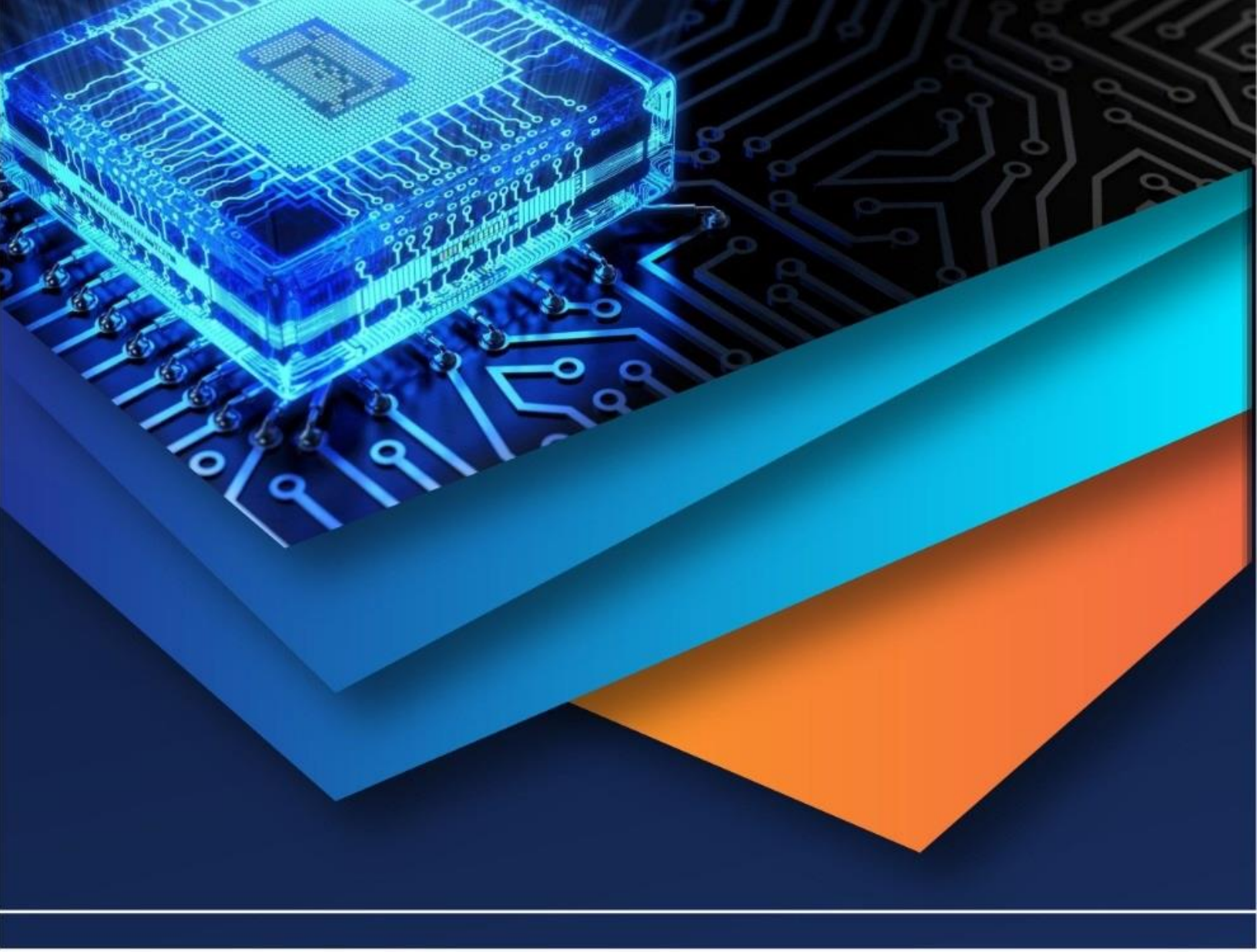

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