

Study of Possible Relation between Drought and Solar Activity in the Territory of Azerbaijan

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Abstract

The paper is devoted to investigation of possible relation between drought and solar activity in the territory of Azerbaijan. The meteorological drought events taken place in recent 117 years in Azerbaijan are studied, and the drought catalogue is compiled in the research work. Two widely used methods in the world practice are analyzed comparatively, and the preferable one is applied in this research work. The relation forms between the drought reiterations and solar activity are examined. As a result, it was determined how amount of precipitations and drought reiterations have been changed and in this period. Relation between solar activity and droughts are determined in the research area on the basis of obtained correlations.

Keywords: precipitation, drought, isohyet, solar activity, drought frequency, SPI, reiteration, fluctuations

1. Introduction

The damage exerted to the economies of the world countries by the drought is estimated at billion dollars. For example, in the territory of Russia the drought exerted an appreciable damage to the economy of Rostov, Orenburg and Ulyanov regions in the last 10 years. Because of this natural event in 2009 the crop in 3,6 million hectares area were exterminated, and in order to compensate this damage some billion roubles were transferred from the state budget.

At present, about 17 regions of Great Britain are bearing the great difficulties of drought, about 35 millions of the British are suffering because of water shortage. According to the opinion of the researchers of environmental protection the limitation for the water use is intended.

The level of damages exerted by drought is also great in the territory of Azerbaijan. According to the data of 1984 and 1986, it was determined that only because of drought and floods, Azerbaijan lost approximately 3 million dollars. The long-term drought has taken place in the region exerts a serious influence on the level fluctuations of the Caspian Sea. For example, in 1930-1940s because of the drought lasted approximately 10 years in the East European plain (in the basin of Volga) the level of Caspian lowered sharply (2,5 metres). On the contrary, in 1978-1995s as a result of increase of precipitations the level of Caspian became risen.

At present the study of drought prognosis is of a very serious problem having economical importance for all the world countries.

2. Research Method

The standardized precipitation index (SPI) method is mostly used in the Western countries for determination of drought years.

This index is estimated on the following formula:

$$SPI = \frac{X_i - \bar{X}}{S_x} \quad (1)$$

here X_i - amount of atmospheric precipitations (annual or monthly) for every year; \bar{X} - average estimation of precipitation number; S_x - average square inclination.

The degree of drought rigour is determined on the basis of SPI method given as in the following table (Table 1).

SPI	Degree of drought
0,0-(-0,99)	Weak
(-1,0)-(-1,49)	Middle
(-1,5)-(-1,99)	Rigorous
-2,0 or less	Very rigorous

Table 1: Degree of Drought Rigour on the SPI Method

The solution of this problem for the territory of Azerbaijan was considered on the basis of SPI method suggested by Ped (1973) and used in the Western countries (Mc Keetal). As a result of comparative analysis, though it is rather difficult, the second method was determined more effective.

Thus, while compiling the drought catalogue for the territory of Azerbaijan the calculations were carried out by taking into account the formula suggested by Ped, and accepting the norm of precipitations lower than 80% (Imanov and Mammadov, 2011).

$$S_i(t) = \frac{\Delta T}{\sigma_T} - \frac{\Delta R}{\sigma_R} \quad (2)$$

ΔT and ΔR - temperature and anomalies of precipitation; σ_T and σ_R - temperature and average square fluctuations of anomalies of precipitation.

While calculating the following gradations were accepted for the drought index S_i .

- a) $1 \leq S_i(t) < 2$ - weak drought;
- b) $2 \leq S_i(t) \leq 3$ - mild drought
- c) $S_i(t) > 3$ - rigorous drought

It is known that the long - termly weak droughts are more dangerous than short-termly other drought types.

3. Results of Analysis

It is known that the XX century is characterized by three different climatic fluctuations: 1891-1940 – rise in temperature; 1941-1975 – fall of temperature; 1976-2008 – rise in temperature. The analysis of drought was carried out taking into account of these periods. The distribution of the amount of precipitations was changeable in those periods. The amount of precipitations decreased recent 15-20 years in arid zones about 50 mm, middle-mountain territories 100 mm and in alpine one 150 mm in comparison with previous cold period. The amount of precipitations in the territories of foothills increases a little in comparison with plain territories. As it is known, in the foothills of Major Caucasus and Minor Caucasus in connection with rising of height the increase of amount of precipitations is observed.

Thus, in both territories at the heights of 200-500 m above sea level the annual amount of precipitations fluctuates between 400-500 mm. The isohyets in these territories stretch from north-east foothills to north-west foothills of Major Caucasus. But in Minor Caucasus the same estimated isohyets stretch from Araz-side territories to north - westward – Gazakh - Aghstafa direction. In Highland Garabagh the average annual amount of precipitations (on the data up to 1990) fluctuates between 600-700 mm. In the plain part of Lenkaran the amount of precipitations is 400-500 mm.

Beginning from the middle mountainous territories to highland towards of the republic the amount of precipitations (from 600-700 mm to 1000-1200 mm) increases sharply. The corresponding states of isohyets passing through the territories of Guba, Ismayilli regions turn towards north-west direction.

But in highland parts parallel to 600-700 mm isohyets the distribution of 1000-1200 mm isohyets towards the Gabala, Zagatala regions is observed. The same estimated isohyets in Talysh pass through 1000 m heights above sea level.

The precipitation distributions are comparatively changeable in Nakhichevan. Here the least precipitation falls in Araz-side territories – less than 250 mm, but the most amount – 400 mm is observed in north-east regions.

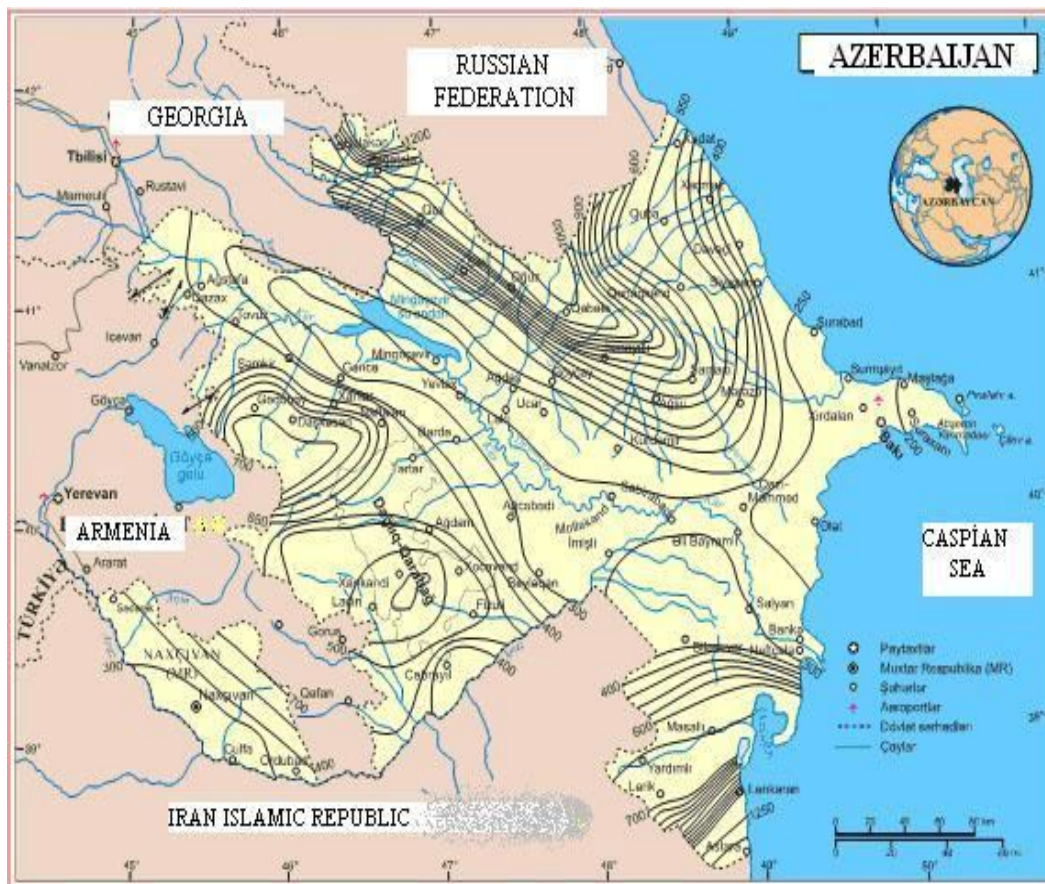


Figure 1: Average Annual Precipitations in the Territory of Azerbaijan

The researches carried out showed that the average annual distributions of falling precipitations recent years became decreased in the territory of Azerbaijan. This decrease up to the highland territories reaches 100-150 mm and in the highland territories 150-200 mm.

So, the decrease of amount of precipitations in the territory of republic is one of the indices of climatic fluctuations, and it is also one of the reasons of increase of drought reiterations.

The different intensively drought reiterations for winter season are given in the Table 2. The weak droughts for winter season mostly took place in 1891-1940 and 1941-1975. So, the weak droughts taken place in mentioned periods are of 75-85%. And the droughts taken place in 1976-2008 fluctuated within 25-15%. The reiteration of weak droughts mostly observed in Guba and Ganja regions make 47%. The mild and strong droughts most of all took place in 1941-1975 52%. So, the droughts taken place in winter season within the recent 117 years are as followings: weak - 61,4%, mild – 30,2% and strong – 8,4%. The droughts taken place during 1998-2008 make 12,7% of all drought years (Table 2).

Region	Reiteration of drought, %	Periods		
		1891-1940	1941-1970	1971-2008
Weak drought				
Absheron	16.1	1892, 1899, 1901, 1916, 1917, 1924, 1926, 1938	1941, 1960, 1961, 1962, 1963, 1970	1981, 1986, 1987, 1988, 2000
Guba	14.4	1897, 1898, 1902, 1936	1941, 1948, 1952, 1960, 1968	1971, 1981, 1983, 1987, 2000, 2002, 2005, 2007
Zagatala	16.4	1895, 1902, 1904, 1910, 1915, 1916, 1923, 1936	1946, 1953, 1955, 1961, 1965, 1970	1982, 1983, 2001, 2002, 2004
Ganja	16.1	1899, 1914, 1915, 1926, 1939	1941, 1946, 1948, 1961, 1963	1979, 1982, 1983, 1987, 1995, 2000, 2002, 2004, 2005
Shusha	12.5	1895, 1902, 1910, 1914, 1916, 1917, 1922, 1926	1944, 1958, 1961, 1963	1981, 1983, 1987
Nakhchivan	19.2	1899, 1910, 1912, 1916, 1926, 1930, 1936, 1938, 1939	1941, 1943, 1951, 1952, 1956, 1961, 1962, 1966	1996, 2001, 2002
Jafarkhan	18.5	-	1958, 1961, 1963, 1968	1975, 1983, 1994, 2002, 2004
Lenkaran	11.5	1892, 1895, 1901, 1902, 1915, 1917, 1919, 1923, 1936	1960, 1962, 1967, 1968	1996, 2000
Mild droughts				
Absheron	8.5	1902, 1914, 1923, 1936	1948, 1953, 1955, 1958, 1968	2001
Guba	7.6	-	1953, 1955, 1958, 1962, 1963	-
Zagatala	5.5	1892, 1901, 1918, 1924	1948, 1958, 1962	1994
Ganja	7.6	1916, 1936	1953, 1962	1981, 1989, 1997, 2001, 2007
Shusha	12.5	1915, 1924, 1936	1953, 1955, 1960, 1962, 1966, 1970	
Nakhchivan	11.0	1902, 1917, 1924	1948, 1953, 1955, 1958, 1960, 1963	1981, 1999
Jafarkhan	5.6		1955, 1970	2001
Lenkaran	8.8	1914, 1938	1944, 1948, 1953, 1958, 1962, 1970	1981, 1983, 2004
Strong droughts				
Absheron	0.8	-	1966	
Guba	2.5	-	1966	1999, 2001
Zagatala	4.1		1966	1981, 1999
Ganja	2.5	-	1958, 1966	1999
Shusha	1.8	1901	1948	
Nakhchivan	0.0	-	-	-
Jafarkhan	3.7			1981, 1999
Lenkaran	3.5	-	1955, 1966	1981, 2002

Table 2: The Years of Reiteration of Different Intensely Droughts Observed in Winter Season on the Territory of Azerbaijan

The years of reiterations of different intensely droughts observed in spring season on the territory of Azerbaijan are given in the Table 3. As it is seen from the Table the droughts are as followings: weak-57,2%, mild-34% and strong-8,8%. The mild and strong droughts basically reiterated during the 1941-2008. It was determined that the droughts taken place within the 1891-1940 were: weak-22,6%, mild-8%, strong-1,3%. The droughts taken place in 1941-1975 were: weak-33,6%, mild-15%, strong-3,5%. In 1976-2008 the situation was as followings: weak-17,7%, mild-5,3%, strong-4%. The droughts taken place in 1998-2008 consist of 13,2% out of all drought years (Table 3).

Region	Reiteration of drought, %	Periods		
		1891-1940	1941-1970	1971-2008
Weak droughts				
Absheron	16.1	1899, 1903, 1916, 1921, 1926, 1930, 1938	1941, 1947, 1950, 1953, 1957, 1958, 1970	1971, 1977, 1999, 2005, 2006
Guba	16.1	1892, 1901, 1903, 1906, 1909, 1935, 1939	1951, 1953, 1958, 1964, 1968	1977, 1979, 1983, 1997, 1998, 2001, 2005
Zagatala	11.0	1891, 1892, 1923, 1924, 1925, 1930, 1934, 1935	1941, 1957, 1958, 1968	1977, 1979, 1992, 2001
Ganja	13.6	1901, 1909, 1914, 1917, 1926, 1930, 1935, 1939	1944, 1950, 1953, 1958, 1961, 1962	1977, 2006
Shusha	14.3	1901, 1902, 1907, 1909, 1912, 1918, 1924, 1926, 1930, 1935, 1938, 1940	1944, 1946, 1962, 1968	1971, 1987
Nakhchivan	15.1	1901, 1916, 1922, 1930, 1932, 1935, 1937, 1940	1944, 1952, 1957, 1959, 1961, 1965	1971, 1989, 2001
Jafarkhan	11.1	-	1958, 1970	1971, 1977, 2005, 2006
Lenkaran	15.9	1899, 1906, 1910, 1916, 1922, 1930, 1935	1941, 1944, 1947, 1961, 1962	1971, 1975, 1977, 1979, 1983, 2001, 2006
Mild droughts				
Absheron	14.4	1906, 1910, 1914, 1917, 1925	1944, 1951, 1961, 1962, 1968	1975, 1983, 1989, 1995, 1998, 2001, 2008
Guba	6.8	-	1947, 1950, 1961, 1962, 1970	1975, 1989, 2000
Zagatala	9.6	1901	1950, 1962, 1970	1975, 1995, 2000, 2008
Ganja	8.5	1906, 1932	1957, 1970	1995, 1997, 1998, 1999, 2000, 2007
Shusha	10.7	1914, 1932	1941, 1947, 1951, 1958, 1961	1977
Nakhchivan	12.3	1917, 1925, 1932	1941, 1947, 1950, 1951, 1955, 1958, 1962, 1970	2008
Jafarkhan	13.0	-	1962	1975, 1983, 1989, 1995, 2000, 2001
Lenkaran	6.2	-	1950, 1958, 1970	1977, 1989, 1995, 1998, 2000
Strong droughts				
Absheron	0.8	1901	-	-
Guba	1.7	-	-	1995, 2008
Zagatala	4.1	-	1951, 1961	1989
Ganja	2.5	-	1951	1989, 2008
Shusha	3.6	1917	1970	1989
Nakhchivan	0.0	1899	-	-
Jafarkhan	3.7	-	1961	1998
Lenkaran	4.4	1901, 1917, 1919, 1925	1951	-

Table 3: The Years of Reiteration of Different Intensely Droughts Observed in Spring Season on the Territory of Azerbaijan

The years of reiteration of different intensely droughts observed in summer season on the territory of Azerbaijan are given in the Table 4. Here is also observed that the reiteration of droughts becomes increased in the recent periods as it was in previous seasons. So, 41% of summer droughts were observed in 1891-1940, 22,6% in 1941-1975, 36,2% in 1976-2008. The total indecies of drought years are shared as followings: weak droughts -69,7%, mild droughts-22,7%, strong droughts -7,6%. And the droughts taken place in 1998-2008 form 16,7% of all drought years.

Region	Reiteration of drought, %	Periods		
		1891-1940	1941-1970	1971-2008
Weak drought				
Absheron	21.2	1891, 1892, 1902, 1903, 1913, 1917, 1925, 1927, 1930, 1937, 1938, 1939, 1940	1942, 1957	1986, 1989, 1990, 1991, 1998, 1999, 2000, 2007
Guba	15.3	1899, 1903, 1940	1942, 1948, 1949, 1953, 1954, 1961, 1969	1971, 1979, 1980, 1989, 1990, 1991, 1996, 2004
Zagatala	19.2	1891, 1892, 1894, 1897, 1899, 1902, 1904, 1913, 1930, 1935, 1936, 1938	1941, 1942, 1951, 1954, 1962	1984, 1987, 1991, 1996, 1998, 2005, 2008
Ganja	19.5	1891, 1893, 1897, 1899, 1908, 1910, 1913, 1929, 1930, 1932, 1938	1952, 1953, 1956, 1962, 1966	1971, 1975, 1987, 1995, 1998, 1999, 2007
Shusha	16.1	1891, 1893, 1897, 1901, 1902, 1907, 1911, 1927, 1938, 1940	1961	1971, 1980, 1987, 1989, 1990, 1991
Nakhchivan	24.7	1891, 1892, 1897, 1898, 1901, 1902, 1907, 1908, 1910, 1924, 1925, 1927, 1930, 1940	1941, 1942, 1943, 1948, 1951, 1954, 1955, 1956, 1962, 1965, 1970	1971, 1975, 1989, 1998, 2001, 2006
Jafarkhan	16.7		1966	1989, 1991, 1996, 1997, 1999, 2001, 2002, 2005
Lenkaran	26.5	1902, 1903, 1908, 1910, 1912, 1913, 1914, 1917, 1919, 1924, 1925, 1929, 1930, 1931, 1937	1942, 1948, 1951, 1953, 1960	1972, 1989, 1990, 1991, 1995, 1996, 2000, 2002, 2004, 2005, 2006
Mild droughts				
Absheron	6.8	1901, 1910	1953, 1954, 1966	1972, 1975, 2006
Guba	5.9	1901		1972, 1975, 1986, 1998, 1999, 2005
Zagatala	5.5	1936	1961, 1966	1971, 2000
Ganja	6.8		1941, 1942, 1948, 1949, 1951	1989, 1991, 2001
Shusha	12.5	1892, 1899, 1913	1941, 1942, 1951, 1954, 1956, 1966	1975
Nakhchivan	6.8	1893, 1894, 1913	1949, 1961, 1966	1980, 2000
Jafarkhan	3.7	-	-	1995, 2000
Lenkaran	5.3	1891, 1893, 1901, 1927, 1939	-	2001, 2007
Strong droughts				
Absheron	0.0	-	-	-
Guba	3.4			2000, 2001, 2006, 2007
Zagatala	2.7	1927	-	1975, 2006 -
Ganja	4.2	1927	1954, 1961	2000, 2006
Shusha	2.7	-	1949	-
Nakhchivan	0.0	1899		-
Jafarkhan	3.7			1998, 2006
Lenkaran	0.9		1954	

Table 4: The Years of Reiteration of Different Intensely Droughts Observed in Summer Season on the Territory of Azerbaijan

The years of reiteration of different intensely droughts observed in autumn season are given in the Table 5. The droughts taken place in autumn season are: weak -62,9%, mild-29,9%, strong- 7,2%. The total indices of drought years are shared as followings: 43,3% in 1891-1940, 27,2% - 1941-1975, 42% in 1976-2008. And the droughts taken place in 1998-2008 form 10,6% of all drought years.

So, the carried out studies show that recent years the reiterations become increased approximately 5-6%.

Region	Reiteration of drought, %	Periods		
		1891-1940	1941-1970	1971-2008
Weak droughts				
Absheron	14.4	1896, 1899, 1904, 1912, 1925, 1926, 1929, 1936, 1938	1955, 1960, 1970	1971, 1974, 1979, 1981, 1985
Guba	11.9	1913, 1928, 1931	1950, 1954, 1964, 1966, 1969, 1970	1978, 1979, 1989, 1994, 2004
Zagatala	21.9	1899, 1909, 1912, 1917, 1925, 1929, 1932, 1938	1954, 1957, 1966, 1968	1971, 1974, 1985, 1986, 1989, 1990, 1995, 1996, 2005, 2007, 2008
Ganja	15.3	1899, 1915, 1927, 1928, 1931	1955, 1957, 1960, 1966	1971, 1974, 1981, 1983, 1984, 1994, 1996, 1998, 2001
Shusha	25.0	1893, 1905, 1933, 1938, 1940	1950, 1954, 1960, 1964, 1968, 1970	1971, 1979, 1983, 1985, 1986, 1991
Nakhchivan	17.8	1898, 1915, 1924, 1925, 1926, 1927, 1936, 1940	1942, 1943, 1947, 1950, 1960, 1961, 1962, 1963, 1964, 1970	
Jafarkhan	16.7	-	1955, 1960, 1966	1968, 1974, 1983, 1986, 1992, 2006
Lenkaran	21.2	1899, 1912, 1913, 1917, 1923, 1928, 1933, 1935, 1936, 1938, 1940	1944, 1960	1971, 1972, 1974, 1979, 1984, 1989, 1990, 1991, 1995, 1996, 1999
Mild droughts				
Absheron	9.3	1893, 1909, 1915, 1917, 1918, 1923, 1933	1952, 1954	1990, 2002
Guba	11.0	1933	1952, 1957, 1968	1971, 1974, 1990, 1991, 1998, 2002, 2006, 2007, 2008
Zagatala	8.2	1905, 1919, 1923, 1937	1952, 1964	1981, 1991, 2001
Ganja	5.9	1925	1952, 1968	1985, 1990, 1991, 2008
Shusha	5.4	1912, 1937	-	1974, 1990
Nakhchivan	11.0	1893, 1899, 1918, 1919, 1929, 1937	1944, 1952, 1954, 1955, 1957, 1968	2002
Jafarkhan	9.3			1985, 1990, 1991, 1998, 2002
Lenkaran	3.5	1893, 1937	1952	1981, 2007
Strong droughts				
Absheron	1.7	1905, 1919	-	-
Guba	1.7	1937	-	2001
Zagatala	1.4	1918	-	2002
Ganja	2.5	1937	1954	2002
Shusha	1.8	-	1952	-
Nakhchivan	0.0	1897, 1905	-	-
Jafarkhan	0.0			
Lenkaran	3.5	1905, 1909,	1954	2002

Table 5: The Years of Reiteration of Different Intensely Droughts Observed in Autumn Season in the Territory Azerbaijan

So, the study of drought catalogue shows that from the beginning of second half of the period comprising 1891-1987 the level of reiteration of drought yeares increased in the territory of Azerbaijan. According to the carried out estimation it becomes obvious that the droughts taken place in 1941-1989 form 65-70 % of the total period droughts.

For explaining its reasons the solar activity was studied in the research work and the correlation between solar activity and drought reiterations was calculated for some points of the territory of Azerbaijan. The number of drought years of different points is given in the next columns of the Table 6. As it is seen, the sum of solar spots increases from 375 to 956 towards the 1985, at the same time, approximately with alike regularity, the increase of the number of drought years is also observed. This time the value of correlation coefficient becomes as followings: in Guba - 0,78, in Ganca - 0,67, in Zagatala - 0,56, Absheron - 0,35, in Nakhichevan - 0,26. Being not many of the correlation coefficient in Nakhichevan, as mentioned before, probably is connected with complicated nature of the territory.

Thus, the increase of solar activity in the territory of republic creates basis for decrease of precipitations. Then, by prognostigating the solar activity it is possible to compile the drought prognoses. Long-termly course of the solar activity is given in the Figure 1 ([Http://ru.wikipedia.org/w/index.php](http://ru.wikipedia.org/w/index.php)). As it is seen from the figure, beginning from 2010 the solar activity increases again and this increase will continue 10-11 years.

Many yearly course of drought reiterations for some points of the territory of republic is given in the Figure 3. The state of graphes given for each of three points changes correspondingly to the state of curve attracting the state of solar activity.

Periods	Sum of volf number	Guba (numb.ofseas.)	Ganja (numb.ofseas.)	Zagatala (numb.of Seas.)	Absheron (numb.of Seas.)	Nakhchivan (numb.of seas.)
1902-1913	375	6	5	9	12	9
1914-1923	447	0	6	9	14	8
1924-1933	411	3	12	9	10	16
1934-1944	611	7	10	12	13	20
1945-1954	751	14	14	9	14	16
1955-1964	956	12	14	12	15	24
1965-1976	710	16	8	13	15	11
1977-1987	847	14	11	10	12	10
1988-1997	808	12	12	10	10	9
1998-2007	890	26	23	17	14	10
R		0,78	0,67	0,56	0,35	0,26

Table 6: Relation between Solar Activity and Reiterations of Drought

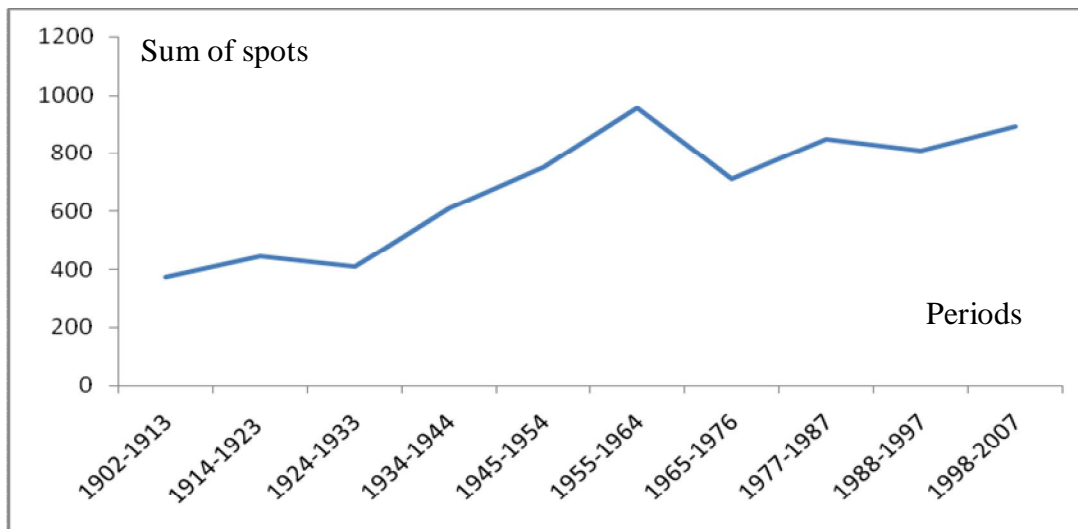


Figure 2: Sum of Spots Observed in Sun Periods

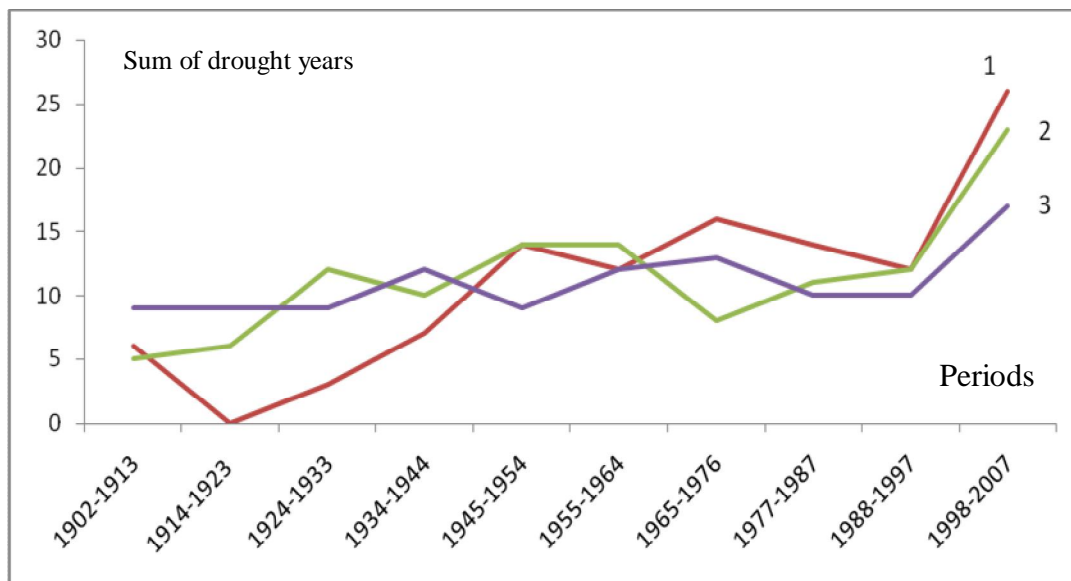


Figure 3: Number of Drought Years in Sun Periods (1- Guba, 2-Ganja, 3-Zaqatala)

4. Conclusion

The comparative analysis of the methods of SPI and Ped, often used in the study of drought events, showed that the second method is more effective. It was determined that the amount of precipitations became decreased and in this period the drought reiterations increased about 5-6%. Basing on these two facts we can suppose that it is the result of mutual relations of these processes.

So, the study of drought catalogues shows that at the beginning of the second half of the periods comprising 1891-1987 the level of reiterations of drought seasons and years became increased. According to the carried out estimation it was determined that the droughts taken place within 1940-1989 form 65-70% of total period droughts.

Thus, the indices of droughts show that beginning from 1940 the tendency increased. Obtained correlations give basis to suggest that there are definite relations between the solar activity and droughts.

References

- Imanov, F.A., Mammadov, A.S. (2011). Investigation of the drought in the subtropical climate zone of Azerbaijan. Azerbaijan works of the geography society. Vol. 16, pp. 266-270.
- Mc Kee, T.B. Doesken, N.J. and Kleist, J. (1993). The Relationship of Drought Frequency and Duration of Time Scales, Reprints, 8th Conference on Applied Climatology. Anaheim, CA. USA, pp.179-184.
- Ped, D.A. (1973). Of the atmosphere droughts and climate features of the dampness too much. Works Hidrometereology Centre of USSR. Publication 156, pp. 39-64.
<http://ru.wikipedia.org/w/index.php>.