

DROUGHT PERIODS ASSESSMENT IN EASTERN GEORGIA USING SPI-3 INDEX IN 1936-2023

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Abstract. In the work detailed statistical analysis of the duration of drought periods D (months) normalized per decade for four SPI-3 categories (agriculture drought; $SPI \leq -1.0$, ≤ -1.5 , ≤ -2.0 and ≤ -2.5) in Eastern Georgia based on observations at 18 meteorological stations during 1936-2023 is presented. The statistical characteristics of D values in 1936-2023, 1936-1975, and 1984-2023 were compared. The variability of D values in 1984-2023 compared to 1936-1975 (ΔD) was assessed. In particular, it was found that ΔD values are different at different points. On average, for eastern Georgia, ΔD values for all SPI categories, except ≤ -2.5 , are increasing (i.e., an increase in the duration of droughts is observed).

Key Words: SPI, atmospheric precipitation, drought categories, drought risk, climate change.

Introduction

Drought is a gradually developing, dangerous natural phenomenon that occurs as a result of less than normal precipitation. Currently, there are many simple and complex indices for studying droughts [1]. One of the most commonly used is the so-called Standardized Precipitation Index (SPI), which is used in more than 70 countries [2]. To calculate this index, only information on precipitation is needed. A special free program is used to calculate SPI [3]. SPI was developed to quantitatively assess the precipitation deficit on various time scales or sliding averaging windows. For example, for agricultural drought, SPI for 3 months is often used [2]. In recent years, a significant number of studies of SPI variations (often in combination with other indices) have been conducted in various countries around the world, including Georgia, to analyze different types of droughts [4-8], taking into account local climate change [9].

This work is a continuation of previous studies [8]. Below is a detailed analysis of the duration of dry periods (months) normalized per decade for different SPI-3 categories in Eastern Georgia during 1936-2023.

Study area, material and methods

Study area – Eastern Georgia, 18 meteorological stations: Paravani (Par), Tsalka (Ts), Bolnisi (Bol), Gardabani (Gar), Tbilisi (Tb), Sagarejo (Sag), Gurjaani (Gur), Dedoplistskaro (Ded), Lagodekhi (Lag), Kvareli (Kv), Telavi (Tel), Tianeti (Tian), Pasanauri (Pas), Gudauri (Gud), Stepantsminda (St), Gori (Gori), Khashuri (Kh) and Shovi (Sh). The altitude range of meteorological stations is from 362 (Lag) to 2194 (Gud) m a.s.l. The study area covers 7 regions of Georgia, including its capital, Tbilisi.

Data from the Georgian National Environment Agency about the monthly sum of atmospheric precipitation in the period from 1936 to 2023 are used. SPI and SPI periods were determined using a special program [3] for 3 months (SPI-3, below – SPI). The analysis of data is carried out with the use of the standard statistical analysis methods. The SPI periods for four categories (Table 1) were determined for three time periods (1936-2023, entire period; 1936-1975, first period; 1984-2023, second period).

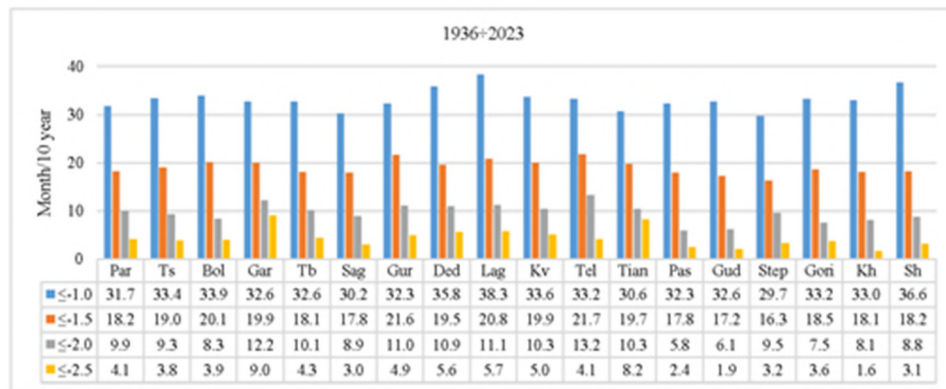
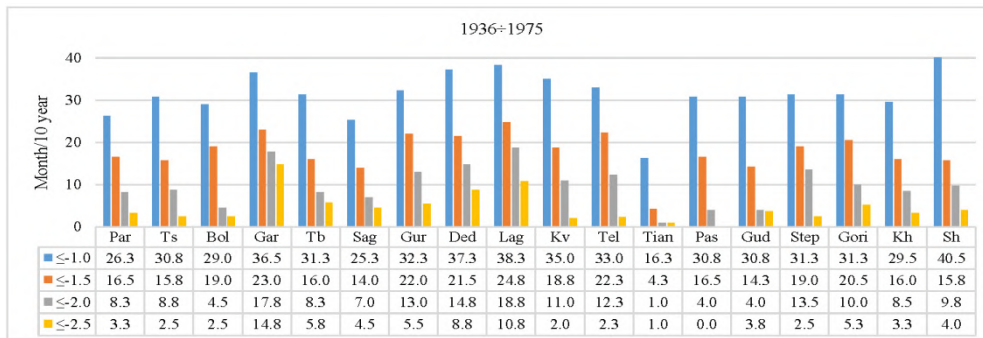
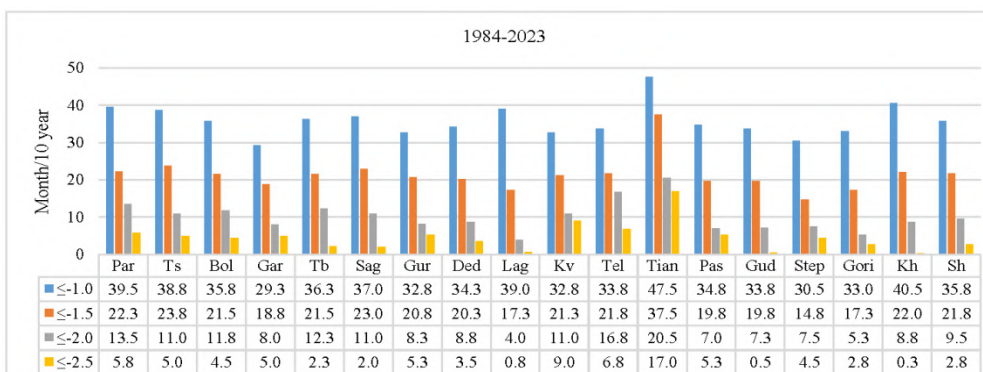
Table 1. SPI category [2].

SPI	Category	SPI	Category
≤ -1.0	Moderate, severe, and extreme dryness	≤ -2.0	Extreme Dryness
≤ -1.5	Severe and extreme dryness	≤ -2.5	Extreme Dryness

The work used standard methods of mathematical statistics [10]. The following designations will be used below: Mean – average values; Min – minimal values; Max – maximal values; St Dev – standard deviation, R – coefficient of linear correlation; D – duration of normalized to decade drought period (month); ΔD – difference between duration of normalized to decade drought periods in 1984-2023 and 1936-1975.

Results

Results in Fig. 1-4 and Table 2 are presented. In Fig. 1-3, data about D values in eastern Georgia in 1936-2023, 1936-1975, and 1984-2023, and in Fig. 4 – data about ΔD values are presented (for different SPI categories). Table 2 presents the statistical characteristics of D and ΔD values for different SPI categories.

**Fig. 1.** D values for different SPI categories in eastern Georgia in 1936-2023.**Fig. 2.** D values for different SPI categories in eastern Georgia in 1936-1975.**Fig. 3.** D values for different SPI categories in eastern Georgia in 1984-2023.

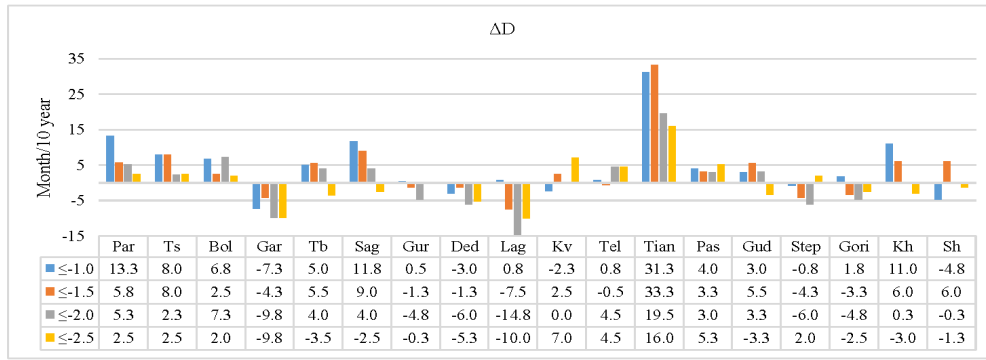


Fig. 4. ΔD values for different SPI categories in eastern Georgia.

Table 2. Statistical characteristics of D and ΔD values for different SPI categories in eastern Georgia.

Variable	≤-1.0	≤-1.5	≤-2.0	≤-2.5	≤-1.0	≤-1.5	≤-2.0	≤-2.5
Year	1936-2023				1936-1975			
Max	38.3	21.7	13.2	9	40.5	24.8	18.8	14.8
Min	29.7	16.3	5.8	1.6	16.3	4.3	1	0
Mean	33.1	19.0	9.5	4.3	31.4	17.8	9.7	4.6
St Dev	2.1	1.5	1.9	1.9	5.5	4.6	4.8	3.7
Correlation Matrix								
≤-1.0	1	0.40	0.15	0.07	1	0.77	0.73	0.52
≤-1.5	0.40	1	0.68	0.54	0.77	1	0.83	0.57
≤-2.0	0.15	0.68	1	0.68	0.73	0.83	1	0.75
≤-2.5	0.07	0.54	0.68	1	0.52	0.57	0.75	1
Year	1984-2023				Difference: (1984-2023) – (1936-1975)			
Max	47.5	37.5	20.5	17	31.3	33.3	19.5	16
Min	29.3	14.8	4	0.3	-7.3	-7.5	-14.8	-10
Mean	35.9	21.4	10.1	4.6	4.4	3.6	0.4	0.0
St Dev	4.2	4.6	4.0	3.8	8.8	8.8	7.6	6.2
Correlation Matrix								
≤-1.0	1	0.80	0.54	0.39	1	0.86	0.78	0.61
≤-1.5	0.80	1	0.82	0.74	0.86	1	0.87	0.70
≤-2.0	0.54	0.82	1	0.74	0.78	0.87	1	0.79
≤-2.5	0.39	0.74	0.74	1	0.61	0.70	0.79	1

In particular, from Fig. 1-4 and Table 2 it follows that the variability of D values for different SPI categories is as follows.

1936-2023. SPI ≤-1.0: $D_{\min} = 29.7$ (Step), $D_{\max} = 38.3$ (Lag), $D_{\text{mean}} = 33.1$; SPI ≤-1.5: $D_{\min} = 16.3$ (Step), $D_{\max} = 21.7$ (Tel), $D_{\text{mean}} = 19.0$; SPI ≤-2.0: $D_{\min} = 5.8$ (Pas), $D_{\max} = 13.2$ (Tel), $D_{\text{mean}} = 9.5$; SPI ≤-2.5: $D_{\min} = 1.6$ (Kh), $D_{\max} = 9.0$ (Gar), $D_{\text{mean}} = 4.3$.

Linear correlation between the parameters under study. $R_{\min} = 0.07$ (Pair SPI: ≤-1.0÷≤-2.5, negligible correlation), $R_{\max} = 0.68$ (Pair SPI: ≤-1.0÷≤-2.0, moderate correlation), $R_{\text{mean}} = 0.42$ (low correlation).

1936-1975. SPI ≤-1.0: $D_{\min} = 16.3$ (Tian), $D_{\max} = 40.5$ (Lag), $D_{\text{mean}} = 31.4$; SPI ≤-1.5: $D_{\min} = 4.3$ (Tian), $D_{\max} = 24.8$ (Lag), $D_{\text{mean}} = 17.8$; SPI ≤-2.0: $D_{\min} = 1.0$ (Tian), $D_{\max} = 18.8$ (Lag), $D_{\text{mean}} = 9.7$; SPI ≤-2.5: $D_{\min} = 0$ (Pas), $D_{\max} = 14.8$ (Gar), $D_{\text{mean}} = 4.6$.

Linear correlation between the parameters under study. $R_{\min} = 0.52$ (Pair SPI: ≤-1.0÷≤-2.5, moderate correlation), $R_{\max} = 0.83$ (Pair SPI: ≤-1.5÷≤-2.0, high correlation), $R_{\text{mean}} = 0.69$ (moderate correlation).

1984-2023. SPI ≤-1.0: $D_{\min} = 29.3$ (Gar), $D_{\max} = 47.5$ (Tian), $D_{\text{mean}} = 35.9$; SPI ≤-1.5: $D_{\min} = 14.8$ (Step), $D_{\max} = 37.5$ (Tian), $D_{\text{mean}} = 21.4$; SPI ≤-2.0: $D_{\min} = 4.0$ (Lag), $D_{\max} = 20.5$ (Tian), $D_{\text{mean}} = 10.1$; SPI ≤-2.5: $D_{\min} = 0.3$ (Kh), $D_{\max} = 17.0$ (Tian), $D_{\text{mean}} = 4.6$.

Linear correlation between the parameters under study. $R_{\min} = 0.39$ (Pair SPI: $\leq -1.0 \div \leq -2.5$, low correlation), $R_{\max} = 0.82$ (Pair SPI: $\leq -1.5 \div \leq -2.0$, high correlation), $R_{\text{mean}} = 0.67$ (moderate correlation).

(1984-2023) – (1936-1975). SPI ≤ -1.0 : $\Delta D_{\min} = -7.3$ (Gar), $\Delta D_{\max} = 31.3$ (Tian), $\Delta D_{\text{mean}} = 4.4$; SPI ≤ -1.5 : $\Delta D_{\min} = -7.5$ (Lag), $\Delta D_{\max} = 33.3$ (Tian), $\Delta D_{\text{mean}} = 3.6$; SPI ≤ -2.0 : $\Delta D_{\min} = -14.8$ (Lag), $\Delta D_{\max} = 19.5$ (Tian), $\Delta D_{\text{mean}} = 0.4$; SPI ≤ -2.5 : $\Delta D_{\min} = -10$ (Lag), $\Delta D_{\max} = 16.0$ (Tian), $\Delta D_{\text{mean}} = 0.0$.

Linear correlation between the parameters under study. $R_{\min} = 0.61$ (Pair SPI: $\leq -1.0 \div \leq -2.5$, moderate correlation), $R_{\max} = 0.87$ (Pair SPI: $\leq -1.5 \div \leq -2.0$, high correlation), $R_{\text{mean}} = 0.77$ (high correlation).

It should be noted that in Paravani, Tsalka, Bolnisi, Tianeti and Pasanauri, for all SPI categories, an increase in the duration of drought is observed (with a maximum in Tianeti), and in Gardabani and Dedoplistskaro, a decrease in this duration is observed (with a maximum in Gardabani). On average, for eastern Georgia, ΔD values for all SPI categories, except ≤ -2.5 , are increasing (i.e., an increase in the duration of droughts is observed).

Conclusion

In the near future will be presented detailed results of SPI complex studies for 1, 3, 6, 9 and 12 months, as well as drought periods for 39 locations of Georgia in 1936-2023.

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