Doi.org/10.36073/1512-0902-2024-135-59-63
UDC 551.576

The structured data for drought evaluation in Georgia

M.Tatishvili, N.Kapanadze, A.Palavandishvili, E.Khutsishvili
Institute of Hydrometeorology of Georgian Tehnical University
m.tatishvili@gtu.ge; marika.tatishvili@yahoo.com

Abstract

The statistical analysis of the total monthly precipitation data of satellite and 50 stations located on the territory of Georgia in 2000-2020 period is presented in the paper. All data have been subjected to QC and the following statistical parameters were calculated: Pearson correlation, mean deviation, and absolute deviation, both for the entire period and for months. The programs R and R-instat are used to calculate and visualize these parameters. The satellite data are removed from the CHIRPS database and the precipitation monthly sums are removed from the CLIDATA database of the National Environment Agency. The stations where more than 50% of data were missing were rejected. In general, the spatial-temporal distribution of precipitation is heterogeneous. The correlation coefficient is in good agreement for all cases, and the absolute deviation shows data scattering, which should be related to the complex relief of Georgia, as well as the heterogeneity of data series. The results are presented in tables and graphs. Such analysis allows developing a Combined Drought Index (CDI) and corresponding drought hazard 5km resolution map. The study is important for climate change assessment, hydrometeorological disaster early warning system, as the territory of Georgia is under the risk of these events.

Keywords—Satellite data, statistical analysis, drought index. early warning system

Introduction

Drought is a frequent phenomenon in Georgia. Its frequency in some areas exceeded 40% in the 80-ies of the last century by certain early estimates. As a result of frequent droughts accompanying the global warming in past decades transformation of many types of natural landscapes has been observed. The desertification probability of steppe and semi-desert landscape of eastern Georgia by the end of the twentieth century has reached 25-30%. According to official figures, by the result of intense droughts area of over than 200 000 ha is strongly affected for present. Property damage caused by drought is very significant [4].

The main meteorological factors for drought formation are dry weather, high temperature and lack of soil producing moisture. The average time of rainless period with precipitation less than 5 mm most important for agriculture is not more than 10-15 days. Besides, the mean rainfall is not more than 200-300 mm during vegetation period on the lowlands. Nevertheless, producing moisture supply is 50-200 mm per one meter of soil that corresponds to the zone of capillary agro-hydrological humidification and full spring rainfall penetration. At the same time active air temperatures sum exceeds 4000° over 10° times, and the mean duration of continuous high temperatures more than 30° is longer than 4 hours.

In the territory of Georgia there are three kinds of drought areas distinguished according to intensity: areas of very severe, severe and moderate droughts. In the super severe drought area that covers a large territory of eastern Georgia as well as a part of western Georgia, the drought may create a critical situation - complete destruction of crops and pastures, extreme fire risk, critical state in water supply.

In the severe drought area that covers a significant territory of western Georgia and mountainous regions, during droughts in these areas loss of crops and pastures, very high fire risk and lack of water are observed.

Drought genesis in Georgia is depending on cyclonic and anticyclone motions. In first case rainy days are frequent and in second dry periods, with high temperature and low humidity of different durations have been taken place. If air masses directed from Arctic are dry and cold. They spread over long territories and stable anticyclone system is established on east-south parts of Europe. During such situation dry period happens in Georgia. If air masses are invading from east high temperature and low humidity dry weather is standing. Such periods are more brutal and dangerous [1].

The observation analysis shows that various degree drought may take place all over the Georgian territory. The event frequency is expected mainly on spring, summer and fall seasons. During winter due to frequent cyclonic and frontal periods dry day duration is less. The drought day number and dry period frequency increase from the Black Sea regions through east or in direction of continental climate.

Based on historical records Georgian territory is under drought 60% repeatability. The most drought regions are Kvemo Kartli, Shiraki and Eldari lowlands and other low parts of eastern parts of Georgia. Those regions are characterized by productive humidity shortage in soils. Two types of productive humidity stocks are common for those places: capillary moisturizing and complete spring wetting. In the first case the productive humidity stock in 1m. soil layer composes 100-200mm, and in other- 50-150mm, while in western Georgia the humidity stock doesn't exceed 400mm. Except natural factors (windy erosion and precipitation decreasing) the anthropogenic loading has significant effect on desertification process too. Namely: unmanaged use of soil, forest and water resources, soil salting.

According to the selected criteria for territory zoning in vegetation period that precipitation small amount equal or less than to 150mm, 3 zone are allocated: I – moisture saturated zone covers whole western Georgia and Highlands of eastern Georgia, upper and middle parts of Alazani river; II –sufficiently humid zone spreads over Shida Kartli valley, western regions of Kartli and adjacent territories of Algeti and Mashavera rivers and lower part of Khvirila river, III-low humidity zone covers Gardabani, Eldari, Shiraki step valleys and Akhaltsikhe Cavern [**2**].

21-30 dry periods are characterizing for Georgia. In Gardabani step valley such dry periods are expected 3times per year, 60 day dry period repeatability is 3% per year and 40-60 day-7%, in Black Sea regions per 10 year. 11-20 dry periods are expected 5-6 times per year in Shida and Kveda Kartli valley and 4 times in Kakheti. In Caucasus Mountains drought isn't dangerous as soil moisture content is sufficient.

Dry periods in arid eastern Georgia last for 80-100 days and ever longer. The maximal dry day duration was recorded on November 1917 and lasted till October 1918, 1986 year was distinguished by dry condition, and also dry weather lasted from May, 2000 till September in whole Georgia.

In Shiraki 150mm or less precipitation repeatability is 19%, in Gardabani-44%, in Akhaltsikhe-40%. This is caused especially by deforestation and forest cutting.

Currently due to negative anthropogenic loading (intense gazing, plowing, sowing, incorrect irrigation, etc) level significantly exceeds selfhealing capabilities of Gareja-Iori region nature, causing its degradation. Desertification process is strengthened [**3**]

The intention of the presented article is to analyze the collected data for environmental monitoring, for this reason the statistical analysis of precipitation monthly sum of 50 stations located on the territory of Georgia and CHIRPS satellite data for the2000-2020 year period has been conducted.

Station data was recovered from the CLIDATA database of the National Environmental Agency (NEA), which has been operating since 2014. Stations were selected based on data continuity and accuracy. After data validation on the stations where data interruption has been detected or measuring sensor transmitted incorrect information due to its malfunction were removed and not analyzed. On the 21 station the observer monitor data and except human factor the unreliability of the data is minimal, and the rest ones was operated by rain gauge produced by VAISALA [4], which by its design does not measure residual precipitation. The VAISALA weather gauges represents a new generation of weighing precipitation gauges. They represent mechanics, the latest high-accuracy load cell technology and advanced measurement control algorithms to ensure high performance, both in liquid and solid precipitation and in all weather conditions [4].

As for satellite data: CHIRPS [5] and IMERG [6] satellite monthly sum for 2000-2020 years were selected for monitoring, Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) [7] is a 35+ year quasi-global rainfall data set. Spanning 50 ° S-50 ° N (and all longitudes) and ranging from 1981 to near-present, CHIRPS incorporates our in-house climatology, CHPclim, 0.05 ° resolution satellite imagery, and in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

METHOD

The Integrated Multi-satellite Retrievals for GPM (IMERG) algorithm combines information from the GPM satellite constellation to estimate precipitation over the majority of the Earth's surface. This algorithm is particularly valuable over the majority of the Earth's surface that lacks precipitation-measuring instruments on the ground. Satellite data retrieved at the corresponding point in the coordinates of the NEA stations.

After data receiving we conduct inventory, which means its visualization, in order to better estimate the transmitting break, for all this we use the program R-studio and R-Instat, the latter is developed [4].

The standardized indices SPI and SPEI classify the precipitation and water balance anomalies with respect to the long term records. The index values directly indicate how frequent the current situation is expected to occur at the location and season of interest given the long term observations [4]. The SPI (standardized precipitation index) classifies the precipitation sums on a particular date with respect to the sums of the same month in all years of the measurement record. For this purpose, the precipitation sums of the whole record within one month around the respective date are transformed into a standard normal distribution around zero [8].

The SPI is nothing else than these transformed precipitation sums. The SPI value hence directly indicates the frequency of the observed precipitation amount in the corresponding month as estimated from the whole observation record. The SPEI (standardized precipitation evapotranspiration index) is calculated in analogy to the SPI, using the cumulative water balance instead of precipitation sums [9]. The SPEI hence represents the standard-normal distributed water balance.

We calculate BIAS that imply the precipitation monthly sums difference measured from satellite and at the ground based station, and also correlation as for whole period as for each month and year, mean absolute errors and standard deviation based on the same principle. The results of the count show that in those stations where the observation period is short, such as Manglisi, it is impossible to conduct statistical analysis; totally eight such stations were identified. The calculation showed the lowest correlation values of 0.33 at Mta-Sabueti station and the maximum 0.72 - Shovi station, the minimal mean absolute error is 18.8 and the maximal_83.2, the smallest standard deviation is 23.4 the largest- 112.6. The R-instat software was used to calculate Pearson correlation and other statistical parameters.

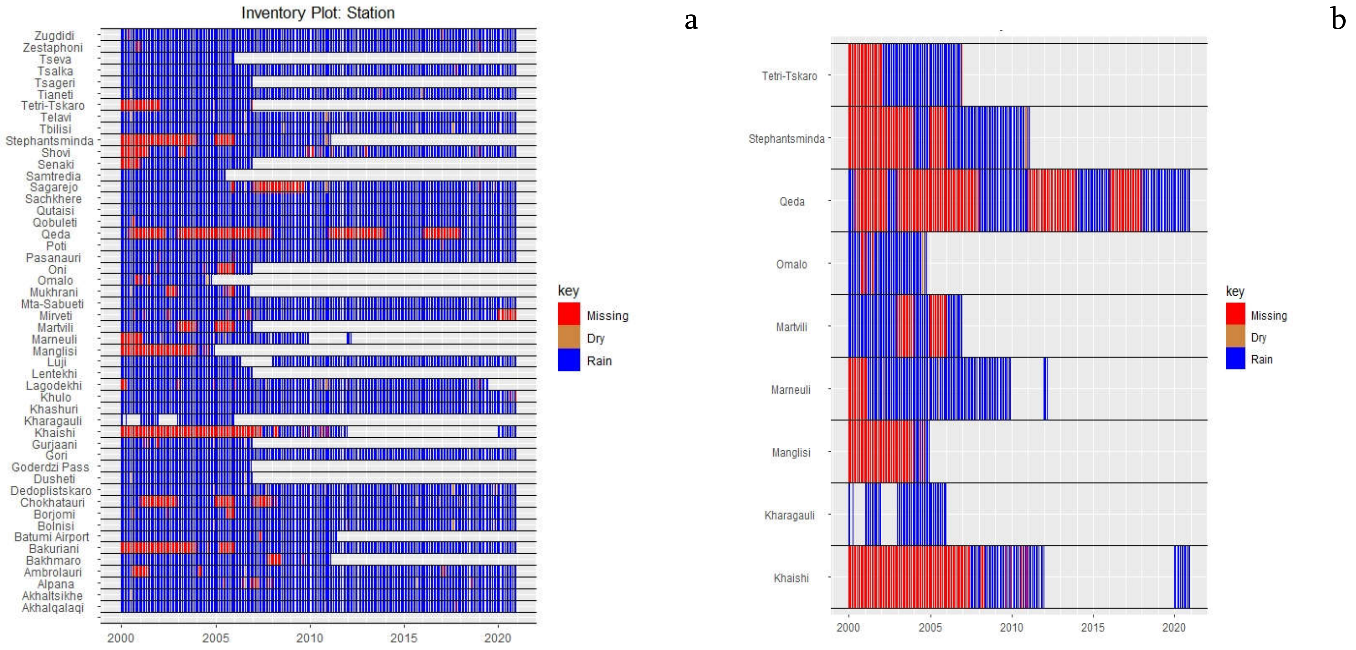

Fig.1. (a) Inventory of 50stations; (b) Stations not subjected to processing

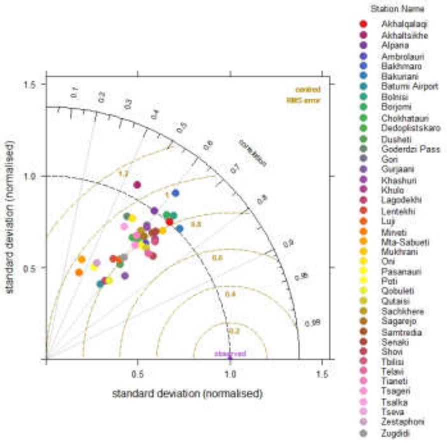

Fig.2. Taylor diagram of standard deviation (normalized) of processed stations

Table1. Statistical parameters of selected 25 stations

Station	correlation	Mean absolute error	Standard deviation	Correlation SPI3month_CHIRPS	Correlation IMERG SPI_3month	Correlation SPI3 month _CHIRPS check
Akhalqalaqi	0.66759	28.7	26.84318	0.416248	0.291970887	0.443102744
Akhaltsikhe	0.460294	38.1	33.55621	0.352573	0.484119499	0.352572913
Batumi Airport	0.58213	83.2	112.5929	0.448736	0.340454562	0.448736396
Borjomi	0.641079	24.1	25.26509	0.244318	0.310999227	0.244318316
Chokhatauri	0.578691	46.6	66.39357	-0.07615	0.165519382	-0.076151789
Gori	0.600696	18.8	23.40047	0.374053	0.424890006	0.374053213
Khashuri	0.602859	20.7	25.35372	0.384062	0.356057737	0.384061993
Mta-Sabueti	0.331451	41.3	51.98547	0.300716	0.31919611	0.300716118
Mukhrani	0.670568	22.5	24.8989	0.235464	-0.102300227	0.235464432
Pasanauri	0.633913	33.4	42.5678	0.290633	0.309023193	0.290632874
Poti	0.456032	72.8	111.9462	0.344086	0.375124979	0.344085861
Qobuleti	0.623388	77.5	102.4052	0.286832	0.363684022	0.286831685
Qutaisi	0.66483	35.2	45.62226	0.483474	0.201479561	0.483474128
Sachkhere	0.592227	26.6	34.78904	0.27458	0.441969055	0.27458026
Sagarejo	0.619239	27.7	37.34099	0.076687	0.233896552	0.076687323
Senaki	0.647958	47.3	60.19786	0.747709	0.544157721	0.747709077
Shovi	0.717298	30.0	36.37001	0.440142	0.34740251	0.440141859
Tbilisi	0.678032	21.1	28.35372	0.208955	0.236983184	0.208954519
Telavi	0.693299	26.0	35.45118	0.271435	0.362963042	0.271434581
Tianeti	0.588555	22.0	31.88968	0.191648	0.321092386	0.191647776
Tsalka	0.504015	32.4	39.38712	0.285891	0.353743633	0.285890812
Zugdidi	0.603897	51.9	62.13524	0.477354	0.417972195	0.477354223

The three month SPI-3 is calculated for data validation for both station and satellite values [7]. The SPI (standardized precipitation index) classifies the precipitation sums on a particular date with respect to the sums of the same month in all years of the measurement record. For this purpose, the precipitation sums of the whole record within one month around the respective date are transformed into a standard normal distribution around zero. The SPI is these transformed precipitation sums [8,9,10]. The SPI value directly indicates the frequency of the observed precipitation amount in the corresponding month as estimated from the whole observation record. Correlation analysis of these two data was conducted, the results obtained are lower than the original correlation, the reasons for this may be the following: satellite error, (the satellite perceives precipitation also solid precipitation), data break at the station, in this case the minimum correlation value fells down to -0.08 and the maximum increases up to 0.75 unit, of course, this index was recalculated for other periods, one month, too and the correlation value did not change, also another R-studio software was used to make sure the result reliability. In this case the correlation values did not change as well (CHIRPS satellite data were used, the 8-th month of 2007 year data are missing for all stations; There are no 2010 and 2011data at all).

Discussion

In the case of IMERG satellite data, the inventory showed that all 50 stations missed first 5-month data in 2000 and June, July in 2004. In general, judging by the fact that CHIRPS have a better Pearson correlation than IMERG, of course in comparison, even in this case we have extracted short period observation or had data breaks. The highest correlation value is recorded at the station Batumi 0.67, and the lowest - 0.01 Mta-Sabueti. Correlations between IMERG and SPI_3 stations give better results. The smallest value of CHIRPS correlation is fixed at station Mukhrani -0.10, and the largest at 0.54- station Senaki.

Based on the SPI correlations of CIRPS and IMERG satellite data, we can say that although the CHIRPS satellite data break was larger than the IMERG, the Pearson correlation index with the station data is higher than IMERG, based on which we can conclude that the CHIRPS satellite data is more valid and subject to further use.

This method is important to make CDI (combined drought index) and 5km resolution monthly drought maps which allow monitoring drought hazard full territory of Georgia. Considering the abovesaid, it is quite important to conduct the similar analysis in order to better understand how the Earth climate is changing, what impact this change will have on people, agriculture crops and the environment.

ლიტერატურა - REFERENCES

1. G.I. Chirakadze. Drought, dry period over Caucasus. Hydro.Met.Izdat. Leningrad. 1980
2. L. Papinashvili. Drought in Georgia. Transactions of the Institute of Hydrometeorology. v. 107. pp. 28-33. 2002. Tbilisi, Georgia
3. Z. Janelidze. On some reasons of desertification and climate aridization of Iori valley. Transactions of the Institute of Hydrometeorology. v 115. pp.51-56.2008. Tbilisi, Georgia
4. Marika Tatishvili, Ana Palavandishvili, Mariam Tsitsagi, Nikoloz Suknidze The Big data for drought monitoring in Georgia Springer Nature ISBN978-3-031-45600-8 Chances and Challenges of Digital Management. ISPC 2022. Springer Proceedings in Business and Economics. Springer, Cham. https://doi.org/10.1007/978-3-031-45601-5_13
5. https://www.chc.ucsb.edu/data/chirps
6. https://gpm.nasa.gov/data/imerg
7. Copernicus European Drought Observatory (EDO): https://edo.jrc.ec.europa.eu/
8. Marika R. Tatishvili, 1Ana M. Palavandishvili, 2Mariam B. Tsitsagi, 2Nikoloz E. SuknidzeThe Use of Structured Data for Drought Evaluation in Georgia Journal of the Georgian Geophysical Society, Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 25(1), 2022, pp.45-51 e-ISSN: 2667-9973, p-ISSN: 1512-1127 https://openjournals.ge/index.php/GGS/article/view/4806/4980
9. Tatishvili M., Palavandishvili A., Tsitsagi M., Gulashvili Z., Suknidze N. DROUGHT EVALUATION BASED ON SPEI, SPI INDICES FOR GEORGIAN TERRITORY International Conference of Young Scientists "Modern Problems of Earth Sciences" Proceedings, ISBN 978-9941-36-044-2, Tbilisi, Georgia, November 21-22, 2022, pp.119-121
10. Mariam Tsitsagi, Zaza Gulashvili, Nana Bolashvili, Marika Tatishvili, Nikoloz Suknidze RELATIONSHIP BETWEEN NORMALISED DIFFERENCE VEGETATION INDEX, PRECIPITATION AND DROUGHT INDICES (CASE OF KAKHETI, GEORGIA) **Multidisciplinary Scientific GeoConference : SGEM; Sofia**, Vol. 22, Iss. 4.1, (2022). DOI:10.5593/sgem2022/4.1/s19.46

უაკ 551.576

სტრუქტურირებული მონაცემები გვალვის შეფასებისთვის საქართველოში/მ.ტატიშვილი, ნ.კაპანაძე, ა.ფალავანდიშვილი, ე.ხუციშვილი/სტუ-ის ჰმი-ის შრომათა კრებული-2024-ტ.135.-გვ.---ინგლ. რეზ.:ქართ., ინგლ. ნაშრომში წარმოდგენილია 2000-2020 წლებში საქართველოს ტერიტორიაზე მდებარე თანამგზავრისა და 50 სადგურის ნალექების ჯამური ყოველთვიური მონაცემების სტატისტიკური ანალიზი. ყველა მონაცემი დაექვემდებარა QC-ს და გამოითვლება შემდეგი სტატისტიკური პარამეტრები: პირსონის კორელაცია, საშუალო გადახრა და აბსოლუტური გადახრა, როგორც მთელი პერიოდისთვის, ასევე თვეების განმავლობაში. პროგრამები R და R-instat გამოიყენება ამ პარამეტრების გამოსათვლელად და ვიზუალიზაციისთვის. სატელიტური მონაცემები ამოღებულია CHIRPS მონაცემთა ბაზიდან და ნალექების ყოველთვიური თანხები ამოღებულია გარემოს ეროვნული სააგენტოს CLIDATA მონაცემთა ბაზიდან. სადგურები, სადაც მონაცემების 50%-ზე მეტი აკლია, უარყოფილი იქნა. ზოგადად, ნალექების სივრცით-დროითი განაწილება არაერთგვაროვანია. კორელაციის კოეფიციენტი კარგად შეესაბამება ყველა შემთხვევისთვის, ხოლო აბსოლუტური გადახრა აჩვენებს მონაცემთა გაფანტვას, რაც დაკავშირებული უნდა იყოს როგორც საქართველოს კომპლექსურ რელიეფთან, ასევე მონაცემთა სერიების ჰეტეროგენურობასთან. შედეგები წარმოდგენილია ცხრილებითა და გრაფიკებით. ასეთი ანალიზი საშუალებას იძლევა შემუშავდეს გვალვის კომბინირებული ინდექსი (CDI) და გვალვის საშიშროების შესაბამისი 5კმ რეზოლუციის რუკა. კვლევა მნიშვნელოვანია კლიმატის ცვლილების შეფასებისთვის, ჰიდრომეტეოროლოგიური კატასტროფების ადრეული გაფრთხილების სისტემისთვის, რადგან საქართველოს ტერიტორია ამ მოვლენების რისკის ქვეშ იმყოფება.