OPEN ACCESS
Journal of Integrated Engineering & Applied Sciences
Volume 2, Issue 1, pp. 48-57, 2024
ISSN: 2960-2661 DOI: https://doi.org/10.5281/zenodo.10884229
Received 22 February 2024 / Accepted 25 March 2024

Impact of Methodological Variations on the Standard Precipitation Index: A Focus on Rainfall-Deficient Scenarios

Petrit Zorba[*1], **Elsuida Hoxha**[2]

[1] Department of Meteorology, Institute of Geoscience, Polytechnic University of Tirana, 1001 Tirana, Albania

[2] Grove School of Engineering, The City College of New York, NY 10031, United States of America

* **Corresponding Author**: petrit.zorba@gmail.com

Abstract

This study delves into the nuances of Standard Precipitation Index (SPI) calculations, especially under conditions where precipitation records for certain months within the dataset are absent. It's crucial to highlight that these gaps in data are not attributed to observational omissions but are instances where no rainfall was actually documented. In such cases, the absent values are substituted with nominal figures, such as 0.1 mm or 0.01 mm, to maintain the continuity of the dataset. Utilizing well-established methodologies for SPI estimation and referencing various models employed in similar analyses, including "RDIT," "SPI Generator," "DrinC," and one developed by our team named "SPI – Alb PZ," we aim to explore the implications and errors arising from the replacement of missing values with 0.1 or 0.01. At first glance, these small values may seem insignificant and may not appear to alter climate assessments for the study area. However, contrary to suggestions from some authors advocating for such replacements in SPI calculation methodologies, our study results demonstrate that this type of modification cannot be recommended. Unfortunately, it leads to higher SPI values and, at times, significantly inflates drought estimations for those specific months when rain values are modified

Keywords: Standard Precipitation Index; drought; data monitoring; meteorology, data modification, SPI error.

1. Introduction

In the recent years, drought phenomena have experienced a significant increase both temporally and spatially in various countries. In this context, achieving an accurate Standard Precipitation Index (SPI) estimation is crucial. Utilizing the right database is the initial mandatory step, and employing the appropriate methodology is equally important.

It is noteworthy that the escalating number of drought occurrences is directly linked to a reduction in precipitation, and in some cases, the complete absence of precipitation for extended periods—not just for a few weeks, but for months or even longer durations. This trend is evident in precipitation data series, which exhibit an increasing number of months without any recorded precipitation compared to previous periods.

Consequently, there is a rise in the occurrence of 0.0 values in the data series, serving as input for the final SPI processing, regardless of the model used. This phenomenon is inherently tied to the methodology applied in such cases.

2. Methodology and Data Analyses

The analyses utilize 30-year-long series of monthly precipitation data from the meteorological station in Korça, Pogradec and Liqenas in Albania, part of the Mediterranean climate, and the City Park of New York, USA, representing a Continental Humid Climate. On the table 1 are shown different categories for classification of wet and drought situation [1].

Table 1. SPI index classification

SPI values	Classification
+2.0 and more	Extreme wet
+1.5 to +1.99	Severe wet
+1.0 to +1.49	Moderately wet
-0.99 to +0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Maintaining the same colour category of table 1 in following tables of this paper helps to easy understand when some change happens on SPI output data, during the monthly precipitation data modification and processing. Several methodological approaches for calculating the Standard Precipitation Index (SPI) suggest altering the values of 0.0 mm in monthly rainfall data series for months without rainfall to 0.1 or 0.01. Importantly, this adjustment is asserted to have no significant impact on climate assessment [2].

Conversely, other base models adopt a different strategy. During the application of the gamma distribution to the rainfall data series (where $Xi > 0$), these models exclude cases of months without rainfall (i.e., those with monthly values of 0.0 mm). Instead, a coefficient q is introduced, and the summation of cases (Σni-cases "with 0.0") is processed separately from the rest. This approach is undertaken to evaluate the corresponding alpha and beta indices essential for applying the gamma distribution in the rainfall series and subsequently calculating the SPI indicator.

In the case of our model, "SPI-AlbPZ," we adhered to the approach where initially, no modification was made to the input for the monthly rainfall data series for the cells with a value of 0.0mm. The outcomes of our model, in this case, demonstrated complete consistency with the results of other compared models, namely "RDIT," "DrinC," and "SPI-Generator," as illustrated in Table 2 (column 5-8, from January to December).

Specifically, we focus on August (row 8, row 260, and row 356) for the years 1931, 1952, and 1960, respectively, where the orange highlighting in column 4 indicates a recorded rainfall value of 0.0 mm. It is noteworthy that the results were consistent across these models.

However, in instances where the values with 0.0 mm rainfall for the period 1931-1960, specifically for the station of Korça in the month of August of 1931, 1952, and 1960 (a total of three cases), were replaced with values of 0.1 and 0.01 mm, there was a discernible change in the SPI indicator values. It's important to note that while the SPI indicator values were affected, other data in the SPI series remained unchanged, as depicted in columns 9 and 10 (from January to December, except modified August).

In Table 2, columns 5 to 8 present the SPI indicator data corresponding to the models "RDIT," "DrinC," "SPI-Generator," and "SPI-AlbPZ." These values were derived from the same rainfall series, wherein only three instances (August of 1931, 1952, and 1960) within the 30-year series for Korça, from 1931 to 1960 recorded 0.0 mm of rainfall in the month of August.

In the highlighted row 8, marked in red, the last two columns (9 and 10) visually demonstrate the impact on the SPI values for the month of August when applying the "SPI-AlbPZ" model. Notably, this change results from the replacement of 0.0 mm rainfall with 0.1 mm and 0.01 mm. Importantly, while the SPI values for August undergo modification, the other data points in the SPI series show no or too minimal alterations.

Table 2. SPI Index Values for August in the Years 1931, 1952, and 1960, and their modification: The modifications range from -1.282 with a yellow background to -2.126 and further to -2.394 with a red background, resulting from changes in precipitation data for this month, transitioning from 0.0 mm to 0.1 mm and to 0.01 mm, respectively.

Nr.	Year	Months	Rain (mm)	RDIT	SPI DrinC	SPI Generator	SPI Alb PZ	0.1	0.01
1	1931	1	61.1	-0.129	-0.130	-0.130	-0.129	-0.129	-0.129
2	1931	2	73.4	0.438	0.440	0.440	0.438	0.438	0.438
3	1931	3	74.5	0.803	0.800	0.800	0.803	0.803	0.803
4	1931	4	103.7	1.260	1.260	1.260	1.259	1.259	1.259
5	1931	5	26.0	-0.763	-0.760	-0.760	-0.763	-0.763	-0.763
6	1931	6	10.6	-1.146	-1.150	-1.150	-1.146	-1.146	-1.146
7	1931	7	5.0	-1.349	-1.350	-1.350	-1.349	-1.349	-1.349
8	1931	8	0.0	-1.282	-1.280	-1.280	-1.282	-2.126	-2.394
9	1931	9	60.3	0.578	0.580	0.580	0.578	0.578	0.578
10	1931	10	53.7	-0.566	-0.570	-0.570	-0.566	-0.566	-0.566
11	1931	11	75.4	-0.255	-0.250	-0.250	-0.255	-0.255	-0.255
12	1931	12	46.0	-0.394	-0.390	-0.390	-0.394	-0.394	-0.394
253	1952	1	74.7	0.253	0.250	0.250	0.253	0.253	0.253
254	1952	2	67.7	0.341	0.340	0.340	0.341	0.341	0.341
255	1952	3	9.6	-1.569	-1.570	-1.570	-1.569	-1.569	-1.569
256	1952	4	17.0	-1.180	-1.180	-1.180	-1.180	-1.180	-1.180
257	1952	5	52.5	0.128	0.130	0.130	0.128	0.128	0.128
258	1952	6	3.9	-1.924	-1.920	-1.920	-1.924	-1.924	-1.924
259	1952	7	34.7	1.029	1.030	1.030	1.029	1.029	1.029
260	1952	8	0.0	-1.282	-1.280	-1.280	-1.282	-2.126	-2.394
261	1952	9	50.7	0.353	0.350	0.350	0.353	0.353	0.353
262	1952	10	54.2	-0.552	-0.550	-0.550	-0.552	-0.552	-0.552
263	1952	11	136.6	0.669	0.670	0.670	0.669	0.669	0.669
264	1952	12	169.5	1.262	1.260	1.260	1.262	1.262	1.262
349	1960	1	131.4	1.476	1.480	1.480	1.476	1.476	1.476
350	1960	2	62.7	0.251	0.250	0.250	0.251	0.251	0.251
351	1960	3	36.8	-0.183	-0.180	-0.180	-0.183	-0.183	-0.183
352	1960	4	109.9	1.365	1.370	1.370	1.365	1.365	1.365
353	1960	5	55.1	0.197	0.200	0.200	0.197	0.197	0.197
354	1960	6	40.5	0.276	0.280	0.280	0.276	0.276	0.276
355	1960	7	19.9	0.193	0.190	0.190	0.193	0.193	0.193
356	1960	8	0.0	-1.282	-1.280	-1.280	-1.282	-2.126	-2.394
357	1960	9	58.5	0.538	0.540	0.540	0.538	0.538	0.538
358	1960	10	82.1	0.117	0.120	0.120	0.117	0.117	0.117
359	1960	11	122.3	0.483	0.480	0.480	0.483	0.483	0.483
360	1960	12	127.2	0.831	0.830	0.830	0.831	0.831	0.831

In this particular scenario, the adjustments led to notable changes or inconsistencies in SPI values, resulting in a reduction by magnitudes of -0.844 and -1.112, respectively. The SPI values shifted from -1.282 to -2.126 and to -2.394. Simultaneously, this alteration caused a shift in the dryness category level, not by one degree but by two categories downward, transitioning from "moderate dryness" to "extreme dryness", see Table 1.

It's noteworthy that this deviation doesn't adhere to a gradual modification of values from one month to another, as observed in the reference base model and attempted by the other three models. In fact, the obtained result without that modification, aligns more closely with what can be considered as a realistic and normal representation of drought situation as shown on rows 5 to 8 on Table 2.

Additionally, another scenario was explored, as outlined in Table 3. In columns 5 to 8, the SPI indicator data were analyzed according to the models "RDIT," "DrinC," "SPI-Generator," and "SPI-AlbPZ." These values were derived from the same rainfall data series, wherein only two instances (on years 1965 and 1968) within the 30-year series for Korça from 1961 to 1990 recorded 0.0 mm of rainfall in the respective months of October and July. Rows 58 and 91, highlighted in red, in the last two columns (9 and 10), illustrate the impact on the SPI values for the respective months of October and July when applying the "SPI-AlbPZ" model. In these cases, rainfall with a value of 0.0 mm was replaced with 0.1 mm and 0.01 mm. Importantly, much like the earlier occurrence, the remaining data points in the SPI series exhibited either no changes or minimal alterations.

Table 3. The SPI index values for October and July, characterized by 0.0 mm precipitation, for the years 1965 and 1968, underwent modifications in October from -1.834 (on an orange background) to -3.203 and to - 3.611 (on a red background). Additionally, for July, the values changed from -1.834 to -2.231 and to -2.686. These modifications correspond to precipitation changes from 0.0 mm to 0.1 mm and to 0.01 mm, respectively.

Year: 1965

49	1965	1	59.6	0.026	0.03	0.03	0.026	0.026	0.026
50	1965	2	84.8	0.546	0.55	0.55	0.546	0.546	0.546
51	1965	3	39.1	-0.782	-0.78	-0.78	-0.782	-0.782	-0.782
52	1965	4	87.1	0.918	0.92	0.92	0.918	0.918	0.918
53	1965	5	53.3	-0.167	-0.17	-0.17	-0.167	-0.167	-0.167
54	1965	6	25.3	-0.665	-0.66	-0.66	-0.665	-0.665	-0.665
55	1965	7	0.7	-1.530	-1.51	-1.51	-1.530	-1.629	-1.543
56	1965	8	11.3	-0.692	-0.69	-0.69	-0.692	-0.692	-0.692
57	1965	9	11.3	-1.523	-1.52	-1.52	-1.523	-1.523	-1.523
58	1965	10	0.0	-1.834	-1.83	-1.83	-1.834	-3.203	-3.611
59	1965	11	152.0	1.013	1.01	1.01	1.013	1.013	1.013
60	1965	12	161.1	1.135	1.14	1.14	1.135	1.135	1.135

Year: 1968

85	1968	1	95.9	0.619	0.62	0.62	0.619	0.619	0.619
86	1968	2	68.9	0.198	0.20	0.20	0.198	0.198	0.198
87	1968	3	47.9	-0.399	-0.40	-0.40	-0.399	-0.399	-0.399
88	1968	4	14.5	-2.154	-2.15	-2.15	-2.154	-2.154	-2.154
89	1968	5	119.7	1.358	1.36	1.36	1.358	1.358	1.358
90	1968	6	64.5	0.855	0.85	0.85	0.855	0.855	0.855
91	1968	7	0.0	-1.834	-1.83	-1.83	-1.834	-2.231	-2.686
92	1968	8	38.0	0.538	0.54	0.54	0.538	0.538	0.538
93	1968	9	34.4	-0.189	-0.19	-0.19	-0.189	-0.189	-0.189
94	1968	10	24.2	-0.909	-0.87	-0.87	-0.909	-0.680	-0.600
95	1968	11	75.2	-0.278	-0.28	-0.28	-0.278	-0.278	-0.278
	1968	12	132.3	0.725	0.72	0.72	0.725	0.725	0.725

In this particular case, the adjustments resulted in noteworthy changes or inconsistencies in SPI values. Specifically, for the month of October, there was a decrease of -1.369 and -1.777, transitioning from -1.834 ("severe drought") to -3.203 ("extreme drought") and to -3.611 ("exceptional drought"). Similarly, for the month of July, the changes amounted to -0.397 and -0.852, moving from -1.834 ("severe drought") to -2.231 ("extreme drought") and to -2.686 ("exceptional drought"). Simultaneously, these modifications led to a shift in the level of drought category from "severe drought" to "extreme drought" and further to "exceptional drought" for both months (referring to Table 1).

When comparing the results obtained exclusively through the use of the "SPI AlbPZ" program, new series of data (specifically, those involving 3 cases of rainfall values of 0.0mm modified to 0.1mm and 0.01mm) for the station in Korça during the 30-year series of the 1931-1960 period were examined alongside other applications. The outcomes are presented in Table 4, revealing complete consistency in results across all four models for the three years that encountered this type of problem: respective months on the years 1931, 1952, and 1960.

This analysis underscores the sensitivity of the SPI value, as it can be significantly altered even by very small changes in the input rainfall values for a specific day or period when the corresponding month experiences no rainfall. When dealing with data processed by various software, distinguishing between "empty cells" and those with a value of "0.0" poses challenges, especially for monthly rainfall values or longer time periods. Despite these challenges, such distinctions hold meteorological significance and meaning.

Table 4. The SPI values for August in the years 1931, 1952, and 1960 (characterized by 0.0 mm precipitation) underwent modifications. The initial value of -1.282, corresponding to 0.0 mm precipitation as mentioned in Table No. 4.1, was replaced with new values of -2.126 (on a red background) for a precipitation modification from 0.0 mm (evidenced in row 8 column 5-8) to 0.1 mm (on the left). Additionally, the value changed to -2.394 on a red background (row 8 and column 5-8) for precipitation changes in the three mentioned cases from 0.0 mm to 0.01 mm (on the right)

Nr.	Year	Months	Rain (mm)	REDIT	SPI DrinC	SPI Generator	SPI AlbPZ
1	1931	1	61.1	-0.129	-0.128	-0.130	-0.129
2	1931	2	73.4	0.438	0.438	0.440	0.438
3	1931	3	74.5	0.803	0.803	0.800	0.803
4	1931	4	103.7	1.260	1.260	1.260	1.259
5	[illegible]	5	26.0	-0.763	-0.763	-0.760	-0.763
6	[illegible]	6	10.6	-1.146	-1.146	-1.150	-1.146
7	[illegible]	7	5.0	-1.349	-1.349	-1.350	-1.349
8	1931	8	0.0	-2.126	-2.126	-2.130	-2.126
9	1931	9	60.3	0.578	0.578	0.580	0.578
10	1931	10	53.7	-0.566	-0.566	-0.570	-0.566
11	1931	11	75.4	-0.255	-0.255	-0.250	-0.255
12	1931	12	46.0	-0.394	-0.394	-0.390	-0.394
253	1952	1	74.7	0.253	0.252	0.250	0.253
254	1952	2	67.7	0.341	0.341	0.340	0.341
255	1952	3	9.6	-1.569	-1.570	-1.570	-1.569
256	1952	4	17.0	-1.180	-1.180	-1.180	-1.180
257	[illegible]	5	52.5	0.128	0.128	0.130	0.128
258	[illegible]	6	3.9	-1.924	-1.925	-1.920	-1.924
259	[illegible]	7	34.7	1.029	1.029	1.030	1.029
260	1952	8	0.0	-2.126	-2.126	-2.130	-2.126
261	1952	9	50.7	0.353	0.353	0.350	0.353
262	1952	10	54.2	-0.552	-0.552	-0.550	-0.552
263	1952	11	136.6	0.669	0.669	0.670	0.669
264	1952	12	169.5	1.262	1.262	1.260	1.262
349	1960	1	131.4	1.476	1.476	1.480	1.476
350	1960	2	62.7	0.251	0.251	0.250	0.251
351	1960	3	36.8	-0.183	-0.183	-0.180	-0.183
352	1960	4	109.9	1.365	1.365	1.370	1.365
353	[illegible]	5	55.1	0.197	0.197	0.200	0.197
354	[illegible]	6	40.5	0.276	0.275	0.280	0.276
355	[illegible]	7	19.9	0.193	0.192	0.190	0.193
356	1960	8	0.0	-2.126	-2.126	-2.130	-2.126
357	1960	9	58.5	0.538	0.538	0.540	0.538
358	1960	10	82.1	0.117	0.117	0.120	0.117
359	1960	11	122.3	0.483	0.483	0.480	0.483
360	1960	12	127.2	0.831	0.831	0.830	0.831

Nr.	Year	Months	Rain (mm)	REDIT	SPI DrinC	SPI Generator	SPI AlbPZ
1	1931	1	61.1	-0.129	-0.128	-0.130	-0.129
2	1931	2	73.4	0.438	0.438	0.440	0.438
3	1931	3	74.5	0.803	0.803	0.800	0.803
4	1931	4	103.7	1.260	1.260	1.260	1.259
5	1931	5	26.0	-0.763	-0.763	-0.760	-0.763
6	[illegible]	6	10.6	-1.146	-1.146	-1.150	-1.146
7	[illegible]	7	5.0	-1.349	-1.349	-1.350	-1.349
8	[illegible]	8	0.0	-2.394	-2.395	-2.390	-2.394
9	1931	9	60.3	0.578	0.578	0.580	0.578
10	1931	10	53.7	-0.566	-0.566	-0.570	-0.566
11	1931	11	75.4	-0.255	-0.255	-0.250	-0.255
12	1931	12	46.0	-0.394	-0.394	-0.390	-0.394
253	1952	1	74.7	0.253	0.252	0.250	0.253
254	1952	2	67.7	0.341	0.341	0.340	0.341
255	1952	3	9.6	-1.569	-1.570	-1.570	-1.569
256	1952	[illegible]	17.0	-1.180	-1.180	-1.180	-1.180
257	1952	5	52.5	0.128	0.128	0.130	0.128
258	[illegible]	[illegible]	3.9	-1.924	-1.925	-1.920	-1.924
259	[illegible]	7	34.7	1.029	1.029	1.030	1.029
260	[illegible]	8	0.0	-2.394	-2.395	-2.390	-2.394
261	1952	9	50.7	0.353	0.353	0.350	0.353
262	1952	10	54.2	-0.552	-0.552	-0.550	-0.552
263	1952	11	136.6	0.669	0.669	0.670	0.669
264	1952	12	169.5	1.262	1.262	1.260	1.262
349	1960	1	131.4	1.476	1.476	1.480	1.476
350	1960	2	62.7	0.251	0.251	0.250	0.251
351	1960	3	36.8	-0.183	-0.183	-0.180	-0.183
352	1960	[illegible]	109.9	1.365	1.365	1.370	1.365
353	1960	5	55.1	0.197	0.197	0.200	0.197
354	[illegible]	[illegible]	40.5	0.276	0.275	0.280	0.276
355	[illegible]	7	19.9	0.193	0.192	0.190	0.193
356	[illegible]	8	0.0	-2.394	-2.395	-2.390	-2.394
357	1960	9	58.5	0.538	0.538	0.540	0.538
358	1960	10	82.1	0.117	0.117	0.120	0.117
359	1960	11	122.3	0.483	0.483	0.480	0.483
360	1960	12	127.2	0.831	0.831	0.830	0.831

From a meteorological perspective, a recorded value of 0.0 mm often corresponds to instances of sporadic showers with only a few drops during the day, primarily observed in warm periods characterized by adiabatic processes and local atmospheric conditions. Additionally, observations of dew may result in the recording of a minimal "rain" amount, which, if detected, might reach a value of 0.1 mm to 0.5 mm.

These phenomena often escape the attention of automatic stations. However, observers who take measurements at specific times may detect and record these small amounts of rainfall, and reflect them in the meteorological station's diaries. This discrepancy occurs because such small amounts, especially during warm periods with daily evaporation rates of up to 5 mm / 24 hours, may not remain in the rain gauge until the observation time / hour, thus going unrecorded in the meteorological station's official records. Nonetheless, it is the observer's responsibility to document this phenomenon in the diary, assigning it a value of 0.0 mm. Alternatively, the observer should make necessary corrections by referring to the WMO guide [1] regarding measurement errors attributed to evaporation. Adjustments ranging from +0.1 mm to +0.4 mm may be required on rainy days, thereby impacting the monthly value accordingly as suggested on literature [1-6].

In the summary of this assessment, the changes in SPI indicator values are highlighted in Table 4. It's noteworthy that these modifications are predominantly in the range (-0.4) up to (-1.8), "translating" into one or two sub-divisions or categories in the classification of the drought phenomenon (colors referring to Table 1). These changes result from alterations in rainfall from 0.0 mm to 0.1 mm and from 0.0 mm to 0.01 mm, with SPI values being further modified, reaching changes close to an average of (-1.0) or even more in certain cases.

In Table 5, the SPI change values concerning the modification of precipitation values from 0.0 to 0.1 mm and to 0.01 mm are presented, as calculated by various models used for the SPI index.

Table 5. The SPI change values, corresponding to precipitation modification from 0.0 to 0.1 mm and from 0.0 to 0.01 mm, as calculated by different models used for the SPI index.

Nr.	Year	Month	SPI for prec. 0.0	SPI for prec. 0.1	SPI for prec. 0.01	SPI change by rain modification from 0.0 to 0.1	SPI change by rain modification of from 0.0 to 0.01
1	1931	August	-1.182	-2.126	-2.396	**-0.844**	**-1.112**
2	1952	August	-1.182	-2.126	-2.396	**-0.844**	**-1.112**
3	1960	August	-1.182	-2.126	-2.396	**-0.844**	**-1.112**
4	1965	October	-1.834	-3.203	-3.611	**-1.369**	**-1.777**
5	1968	July	-1.834	-2.231	-2.686	**-0.397**	**-0.852**

The same type of errors was verified also for 2 other meteorological station near to Korça area in Albania, where modified monthly value of precipitation for only those cases with 0.0 mm (referring to series of 30 years monthly precipitation data) to the new values of 0.1 or 0.01mm produced new emphasized estimation for drought situation as presented on the following table 6. SPI change on those cells get modified by value of -0.957 to -2.329.

Table 6. The SPI change values, corresponding to precipitation modification from 0.0 to 0.1 mm and from 0.0 to 0.01 mm, as calculated by different models used for the SPI index, for meteorological stations of Pogradec and Liqenas.

Meteorological Station	Year	Month	Rain mm	SPI R=0.0 mm	SPI R=0.1 mm	SPI R=0.01 mm	SPI change	SPI change
Pogradec	1995	October	**0.0**	-1.834	**-3.805**	**-4.163**	**-1.971**	**-2.329**
Pogradec	2007	July	**0.0**	-1.834	**-2.791**	**-3.251**	**-0.957**	**-1.417**
Pogradec	2015	December	**0.0**	-1.834	**-3.808**	**-4.163**	**-1.974**	**-2.329**
Pogradec	2019	August	**0.0**	-1.834	**-2.969**	**-3.453**	**-1.135**	**-1.619**
Liqenas	2018	September	**0.0**	-1.834	**-3.434**	**-3.829**	**-1.600**	**-1.996**
Liqenas	2019	August	**0.0**	-1.834	**-3.126**	**-3.584**	**-1.292**	**-1.750**

A graphical representation of these changes is provided in Figure 1. It clearly illustrates how the occurrence of drought is artificially exacerbated by mathematical interventions. This representation undoubtedly conveys values that deviate further from reality. As observed, all models depict a smoother transition of drought situations from one month to another, even when dealing with rainfall values as low as 0.0 mm. To note is also the fact that the nearest month values of SPI don't get any important modification by this modification of cells with 0.0 mm values.

Although the replacement of months with 0.0 mm rainfall values by 0.1 mm or 0.01 mm may initially appear inconsequential for climate assessment, it is crucial to note that when evaluating the SPI indicator, the scenario presents a significant difference that requires careful consideration.

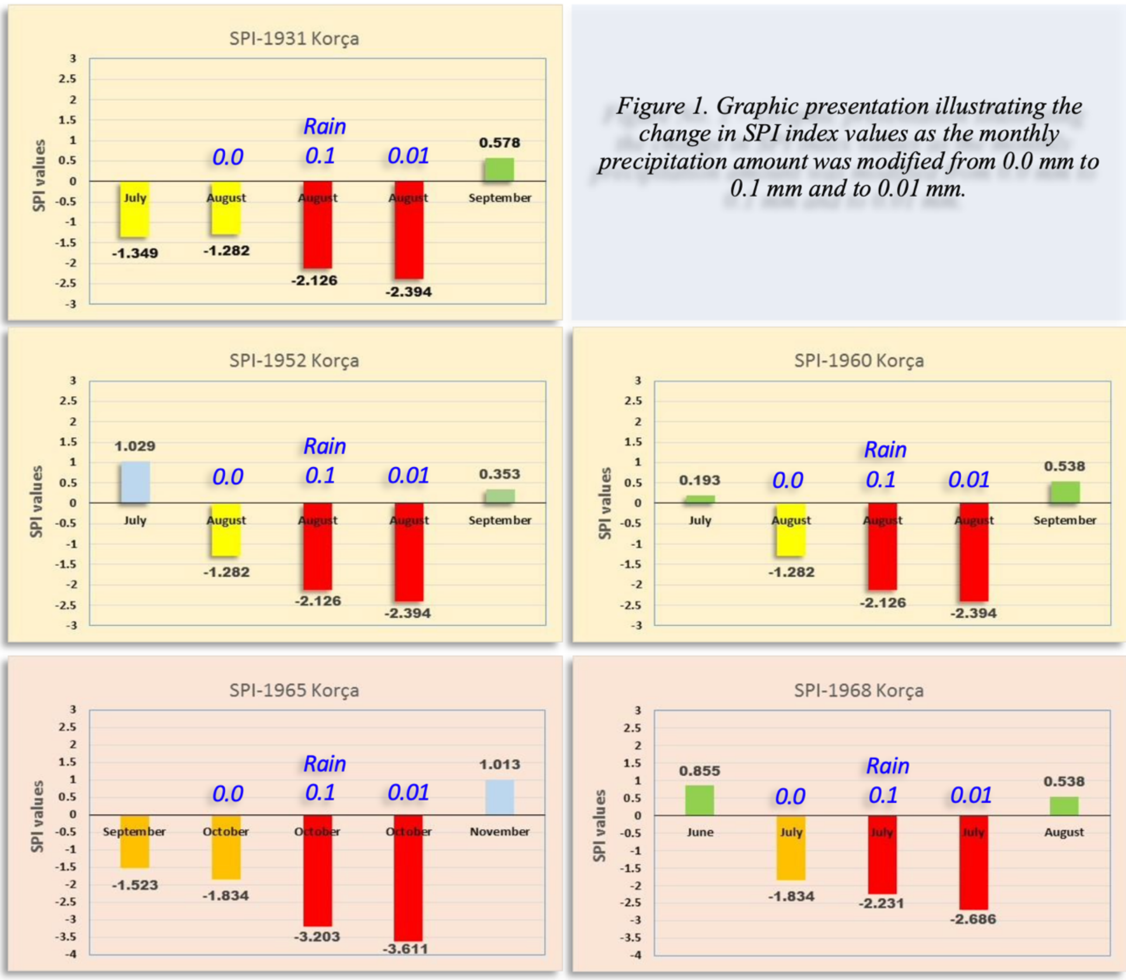

Figure 1. Graphic presentation illustrating the change in SPI index values as the monthly precipitation amount was modified from 0.0 mm to 0.1 mm and to 0.01 mm.

Therefore, based on this analysis, it is suggested that data should not be pre-corrected, and artificial modifications like the ones described should be avoided in rainfall data series for months without rainfall.

Furthermore, it prompts us to exercise caution in cases where 0.1 mm rainfall values are observed and recorded in a particular month or necessary correction should be done, as above mentioned [7-12]. Surprisingly, these instances indicate a more pronounced drought than months with no rainfall at all. The somewhat contradictory nature of these situations with minimal rainfall values necessitates increased attention and analysis, particularly in relation to the stability of the drought phenomenon concerning the preceding and following months.

In the context of information technology or mathematics, a minute rainfall value plays a pivotal role in determining whether a month experiences rainfall or not. In the realm of informatics, a binary concept is employed, classifying the occurrence as either "Yes" or "No."

Yet, when dealing with minuscule values, especially for the purpose of data processing with the application of the gamma distribution to rainfall series, it becomes imperative to pause and carefully handle these diminutive magnitudes [13].

To mitigate these "anomalies", be they derived from "nature", "mathematics", or "methodology", meticulous attention is essential. It is imperative to scrutinize the associated drought or SPI indicator in the context of its coherence with the preceding or succeeding month. This approach ensures a more precise evaluation of the indicator's magnitude in these specific instances, bringing us closer to an accurate representation of reality.

In conclusion of this comprehensive analysis, all discrepancies, anomalies, and errors resulting from the application of various models [11], series with differing time lengths [10], the impact of precipitation values ranging from 1 to 30 mm [12], as well as those introduced by measuring instruments and methodologies involving modifications with values of 0.1 or 0.01, are presented in the following Table 7.

Table 7. The analysed discrepancies for different models, for different length of data series, by modified precipitation and by instrument errors, to the final SPI index values.

Different models (The same length of series)	Different length of series	Precipitation change (mm) (by nature or by methodology)		Measurement errors (mm)
"RDIT" // "DrinC" // "SPI Generator" // "SPI AlbPZ"	90/30 60/30 (years)	1,2,3,4 & 5,10,20,30 (mm)	0.1 and 0.01 (mm)	0.2 mm up to 30% of precipitation
From ±0.1 to ±0.8	From -1.50 to +1.362	-0.148 -0.346 +0.828 +1.334	-0.397 -1.777	

Table 7 that includes also the final results taken and published in other papers based to our study, about other type of errors related to SPI methodology, measurement errors, nature of precipitation, data processing, etc., has the purpose to attract the attention not only of so many types of errors, but also to show the relativity of each of them or the total impact sum of them.

This type of comparison between different source of errors that influence the final output of SPI bring the attention in this paper presentation, especially about the importance of such specific technical modification related to the methodology and associated problem that it is needed to be taken in consideration.

Following a meticulous examination of the outcomes derived from employing various models to assess the SPI index, several key observations emerged by the other analyses and published in different papers that in summary are as follow:

- Despite the prevalent recommendation in the literature for a series of at least 30 years to compute the SPI index, the results obtained exhibit a discernible margin of error.
- While different models employed for SPI index estimation generally demonstrate a minor margin of error, specific instances reveal a substantial error that cannot be disregarded.
- Alterations in the length of precipitation series, even those exceeding 30 years, can lead to noteworthy discrepancies in the classification and ultimate assessment of situations using the SPI index with the same models.

- Minimal variations in precipitation within a given month contribute to changes in SPI values, which, in certain cases, are significant and demand attention. Thus, ensuring high-quality precipitation series is paramount, particularly in cases with low precipitation levels.

To all above mentioned it is necessary to add also the following conclusions related to errors produced by technical modification on the methodology for SPI evaluation and data processing, which in our view shouldn't be done.

4. Conclusion

The main conclusions of our research work are as follows:

- It is advisable not to replace or correct precipitation values of 0.0 mm with modified values of 0.1 mm or 0.01 mm.
- The challenge of low precipitation levels is more pronounced in Mediterranean Climates, with a higher frequency of such cases, compared to Humid Continental Climates. In the meteorological station of City Park of NY-USA, no cases of monthly precipitation data equal to zero was verified for the whole period of analysed observation (1931-2020).
- On the flip side, in the case of naturally occurring situations where monthly rainfall values are exceptionally small, around 0.1 mm, special attention should be devoted to the preceding or following month. This is essential for a more accurate and thorough assessment of the drought situation by considering also the preceding and following month referring to that specific month with extreme drought.

Conflict of interests

The authors would like to confirm that there is no conflict of interests associated with this publication and there is no financial fund for this work that can affect the research outcomes.

References

[1] Standardized Precipitation Index User Guide, WMO-No.1090 (2012). World Meteorological Organization, Geneva 2, Switzerland.

[2] Cornel S.N. Comparative study regarding performance of some software for the calculations of the standardized precipitation index (SPI)", *Analele Universităţii din Oradea, Fascicula Protecţia Mediului*, 2014; 23; 779-788.

[3] Wu H., Hayes M.J., Wilhite D.A., and Svoboda M.D. The Effect of the Length of Record on the Standardized Precipitation Index Calculation", *International Journal of Climatology*, 2014; 25; 505-520.

[4] Guide to Instruments and Methods of Observation Volume V – Quality Assurance and Management of Observing Systems, WMO-No. 8 (2018). World Meteorological Organization, Geneva, Switzerland.

[5] AGRIMETSOFT. Available at https://agrimetsoft.com/calculators/Index Accessed on 18 September 2023.

[6] Zorba P. Estimation of the error in the measurement of atmospheric precipitation and the correction coefficient due to evaporation. *Monthly Climate Bulletin*, 2023; 7(79); 39-47.

[7] Zorba, P., Hoxha, E. A New Approach for Drought Evaluation by Using the SPI Methodology. *Lecture Notes on Multidisciplinary Industrial Engineering*. 2024, p. 304-316.

[8] DrinC. Available at https://drought-software.com Accessed on 18 September 2023.

[9] SPI Generator. Available at https://drought.unl.edu/monitoring/SPI/SPIProgram.aspx Accessed on 18 September 2023.

[10] Zorba P., Hoxha E. Comparative Analysis of SPI Errors Generated by Software Tools Using Data Series of Different Lengths for Meteorological Stations in Mediterranean and Humid Continental Climates. *Monthly Climate Bulletin*, 2023; 7(73); p. 24-30.

[11] Zorba P., Hoxha E. A novel model for Standardized Precipitation Index (SPI) analysis and the calculation of errors produced by various software programs using meteorological data from stations of diverse climate types. Monthly Climate Bulletin, 2023; 7(75); 22-31.

[12] Zorba P., Hoxha E. Drought SPI Index, highly impacted by precipitation measurement errors, especially in extreme weather event" Monthly Climate Bulletin, 2023; 7(81).

[13] Arléry R., Grisollet H., Guilmet B. (1973). Climatologie – Méthodes et Pratiques. Gauthier-Vilars Éditeur, Paris - Bruxelles – Montréal.

Cite this article as: Zorba P., Hoxha E. Impact of Methodological Variations on the Standard Precipitation Index: A Focus on Rainfall-Deficient Scenarios, *Journal of Integrated Engineering and Applied Sciences*. 2024; 2(1); 48-57.