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Drought Assessment under Climate Change Using SPI, SPEI, and the Hydrothermal Coefficient: A Case Study of the Myzeqe Plain, Albania

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ABSTRACT: *This material presents a scientific analysis dedicated to agricultural droughts in the Myzeqe Plain in Albania. The Myzeqe Plain is the largest plain area of the country, part of the Western Lowlands and also the main agricultural region of the country.*

Albania's Mediterranean climate is characterized by hot summers and mild, wet winters. The summer season with hot Mediterranean features and low rainfall makes this territory sensitive to climate change. As a result, analyzing agricultural droughts from the perspective of climate change is of particular importance since they directly affect the increase in economic costs for farmers. The worsening of droughts and the increase in temperatures bring increased costs in irrigation and damage to agricultural crops from excessive heat

In this study, through the use of meteorological data for a period of 60 years (1961-2020) for 6 meteorological stations, the aim is to identify the long-term progress of some of the main drought indicators such as durations without precipitation, Hydrothermal Coefficient, SPI and SPEI. For the summer season where the need for irrigation is most pronounced, 2 days with more than uninterrupted precipitation are observed, as well as a deterioration of other scientific indicators. This assessment can serve as a basis for taking adaptive and preventive measures in the agricultural sector in the Myzeqe region.

KEYWORDS *Agricultural Drought, SPI, SPEI, Hydrothermal Coefficient, Myzeqe Plain*

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I. INTRODUCTION

The normal development of agricultural crops requires a certain amount of heat and water distributed proportionally throughout the year. In general, it is the extreme values (frost, drought, etc.) of the climatic elements that take on the greatest importance, because they determine the absolute limits of the existence and development of vegetation (Laçi, 2005). Drought as a climatic element represents one of the greatest risks with direct effects on agriculture. Geographical regions with high agricultural potential feel the consequences more, directly linked to increased costs and damage to production. According to the World Meteorological Organization, the frequency and intensity of droughts are increasing as a result of global climate change (Organization, 2017b). In particular, Mediterranean regions, including Albania, have been considered "hotspots" for extreme droughts and potential declines in agricultural yields. (Giorgi & Lionello, 2008).

The Myzeqe Plain is the main agricultural region of Albania and is often affected by drought. This situation is a consequence of the rainfall regime that is 3% below the second norm from the first 30 years 1961-1990. The trend of these anomalies is also evident in the monthly distribution as well as in the number of days with rainfall above different thresholds (G. Çela, Papathimiu, & Laci, 2025).

The assessment of agricultural droughts in this area is essential to understand the long-term impact of climate change and to guide adaptation policies in agriculture. This analysis relies on the use of standardized drought indicators such as the Standardized Precipitation Index (SPI) (McKee, Doesken, & Kleist, 1993), Standardized Precipitation Evapotranspiration Index (SPEI)(Vicente-Serrano, Beguería, & López-Moreno, 2010), Hydrothermal Coefficient according to Selyaninov (1958) (Nikolaev, 2020), which was first analyzed in Albania in various publications even before the 1990s(Mandili, 1975). Other national assessments regarding the assessment of agricultural droughts have also been carried out by the Institute of Geosciences through various published publications such as the Monthly Climatic Bulletin (Zorba, 2024).

This study aims to present the performance of the main indicators of agricultural droughts in the long term by considering 6 meteorological measurement sites for a 60-year period consisting of two climate norms. The analysis of meteorological data on a long-term basis and the comparison between reference periods, such as 1961–1990 and 1991–2020, is essential for assessing the performance of droughts, as it helps in identifying structural changes in climate regimes and their impact on agriculture. (Organization, 2017a; Spinoni, Naumann, & Vogt, 2015).

II. DATABASE AND METHODOLOGY

The meteorological database under consideration concerns daily values of precipitation and air temperatures from which the necessary technical and scientific processing has been carried out. The database is complete and uninterrupted in time for 6 meteorological measurement sites, which are Divjaka, Kryevidhi, Lushnja, Gorre, Fier and Vlora. This database is obtained through the National Meteorological Monitoring System. To fill the data gaps, the reanalyzed Copernicus ERA5 dataset was used.((C3S), 2023). Based on scientific methodology for filling the gaps in precipitation, it has been possible to fill in the missing data from meteorological observations.

The nature of meteorological data obtained from classical stations is developed through daily observations, every day at 7:00 am depending on the category of the measurement site. On the other hand, the nature of the reanalyzed Copernicus data consists of other grid-type data with hourly resolution. In order to have temporal compatibility of the observed daily data with the reanalyzed ones, through scientific techniques of applications with different codes in python, it has been possible to build daily networks through the formula:

$$\mathrm{P}^{24h} = \sum_{t2=(23:00-06:00)}^{06:00\ t1} Pt$$

Where:

- P^{24h} is the daily cumulative precipitation
- Pt represents the precipitation reanalyzed every hour t by Copernicus, the sum of the precipitation of hour t_1 06:00 UTC of the current day and the precipitation of t_2 ëhere is the accumulative precipitation of the previous day minus the precipitation of hour 06:00 UTC(G. Çela et al., 2025).

This formula generates precipitation data With better correlation ëith observed data. Copernicus Climate Data Store (CDS) data, Which provides global climate data with a spatial resolution of 0.25° and daily/hourly frequency (Hersbach et al., 2020). The data was downloaded in NetCDF format via the CDS API and processed in Python using the xarray and pandas libraries to extract time series at specific geographic points and export them to Excel database formats.(Muñoz-Sabater et al., 2021). According to this standard, the possibilities of an accurate scientific analysis are fulfilled.

In this study, scientific indicators of agricultural drought analysis such as the duration of days without continuous rainfall, Standard Precipitation Index, Standardized Precipitation Evapotranspiration Index (SPEI) and the Hydrothermal Coefficient (HC) according to the Selyaninov formula were used. These indicators offer an integrated approach to analyzing the lack of moisture in relation to precipitation and temperature, reflecting in a differentiated way the climatic impacts on agriculture. The calculation of the Hydrothermal Coefficient was carried out taking into account the summer season as the month with the most pronounced water needs in agricultural areas. The methodology followed has been used previously in Albania and the analysis of this indicator serves to study the current state of droughts based on the progress over the years. The Hydrothermal Coefficient is applied through the formula:

$$K = \frac{\mathrm{SU}}{0.18 * (\mathrm{ST10°C})}$$

Where K is the Hydrothermal Coefficient, SU is the precipitation height for the considered period and ST10°C is the multi-year average sum of active temperatures above or equal to 10°C for the time referred to. When calculations using the formula give K=1 then we are dealing with humid conditions and the smaller this coefficient is, specifically below 0.3 we are on the border of the desert.(Mandili, 1975).

SPI is a statistical indicator based only on precipitation by measuring the deviation of the amount of precipitation from the historical average of a certain period of time taken into study. In this case, priority has been given to the 3-month SPI, where, as for 60 years, only the warm period of the year (April-September) with the most pronounced problems with precipitation, the period in which agricultural plants have the most increased water needs, has been taken into consideration. SPI is calculated by fitting the precipitation time series to a Gamma distribution and then transforming it into a standard normal distribution. Negative values indicate dry conditions, while positive values indicate wet conditions.(McKee et al., 1993).

The Standardized Precipitation Evapotranspiration Index (SPEI) is a more advanced method of SPI in which daily air temperature is also taken into account through potential evapotranspiration (PET), usually with the Thornthwaite method.(Thornthwaite, 1948). SPEI is one of the most advanced indicators in assessing climatic drought, especially in the context of global temperature changes. (Vicente-Serrano et al., 2010).

SPEI is calculated using the formula:

$$D_a = P_a - PET_a$$

Where:

- D_a: monthly moisture balance
- P_a: monthly precipitation (mm)
- PET_a: monthly potential evaporation (mm)

III. RESULTS

Meteorological droughts have a significant impact on the agricultural economy, especially in the summer season. The uninterrupted duration of days without precipitation is one of the main indicators of droughts. Figure No. 1 shows the multi-year average duration of days without precipitation in the Myzeqe area during the time periods of the two climatic norms during the summer season, which is also the period with the greatest needs for irrigation.

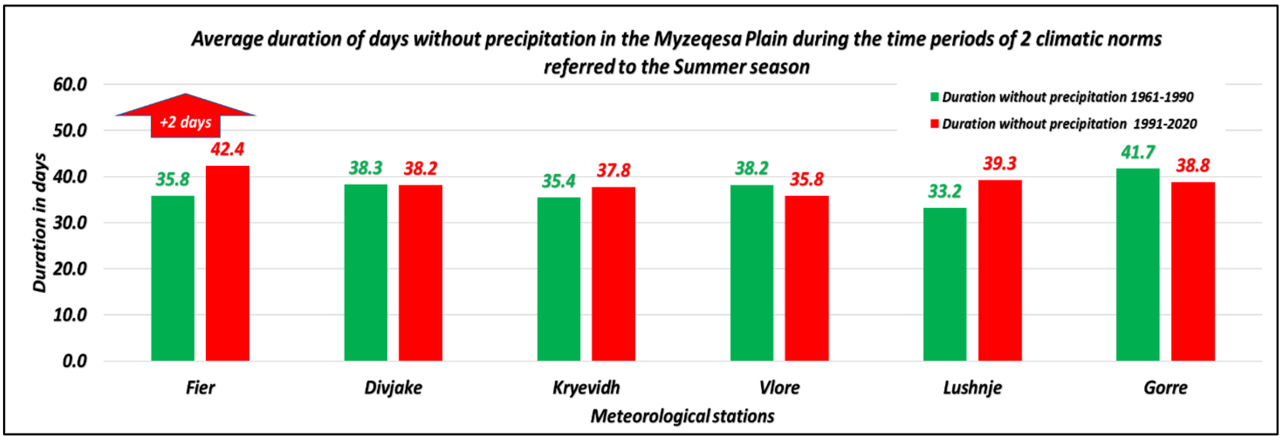

Fig. 1. Average uninterrupted duration of days without precipitation in the Meteorological Observation Stations of the Myzeqe Plain, referring to the two climate norms 1961-1990 and 1991-2020

In terms of climate change, during the second climate norm, an increasing trend is observed with 2 more days without precipitation than in the period 1961-1990. This anomaly is an evident indicator of pronounced meteorological droughts lasting over a month which have consequences on irrigation needs. As for the annual analysis of the multi-year average duration of days without precipitation, these statistics constitute 90.7% of the duration. The Myzeqe Plain, although it is a uniform territory, from a physical-geographical point of view, for specific indicators, appears diverse with micro-climatic diversity. The nature of precipitation with low amounts and local features brings differentiation from one meteorological measurement site to another. This is an important indicator that clearly shows that periods without precipitation are concentrated in the summer season and only less than 10% is extended to the rest of the year(G. Çela, Zorba, Petrit., Gjoni, Anira., Bardhi, Azem., 2024).

In agrometeorological literature, the Hydrothermal Coefficient is also used to estimate the humidity level of a place(Mandili, 1975). The calculation of the Hydrothermal Coefficient was carried out on an annual and seasonal basis for the period 1961-2020, which in annual values are presented in figure no.2. The Myzeqe Plain is characterized by a noticeable downward trend that translates into a worsening of the drought situation. The fluctuations from year to year of this indicator are noticeable and in the last 5 years values above 1.0 have been presented. This phenomenon, when compared with the complete downward trend of the 60 years, especially in the period from 1985 to 2000, takes on positive features, but does not affect the overall linear trend.

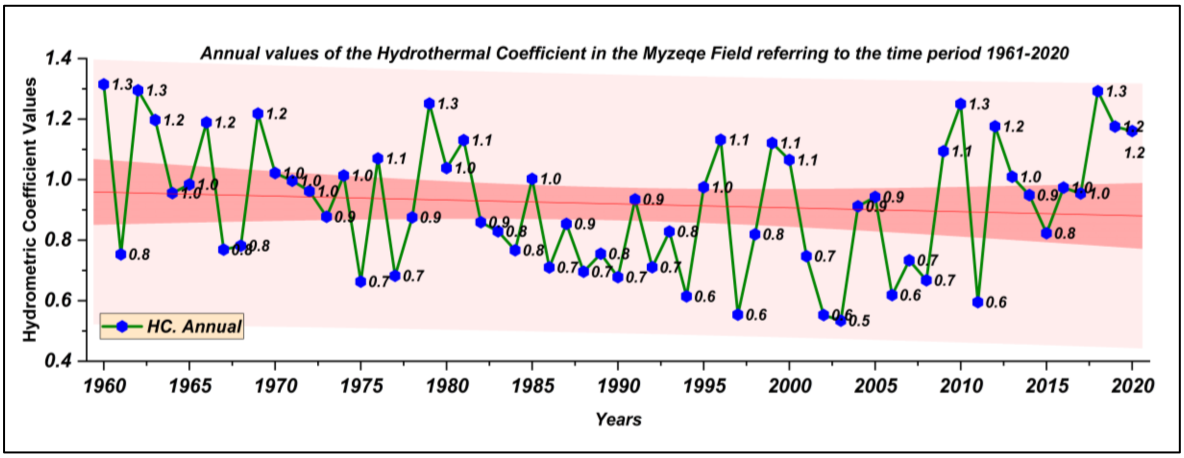

Fig. 2. Annual values of the hydrothermal coefficient in the Myzeqe Field during the time period 1961-2020

The most accurate and practical representation of the Hydrothermal Coefficient is achieved through a multi-year seasonal analysis, as shown in Figure 3. This analysis covers the annual trend as well as three specific timeframes: the cold period (October–March), the warm period (April–September), and the summer season (June–August). In nearly all of the examined periods, the Hydrothermal Coefficient exhibits a clear downward trend. The only exception is the warm period of the year, which shows a slight increasing trend.

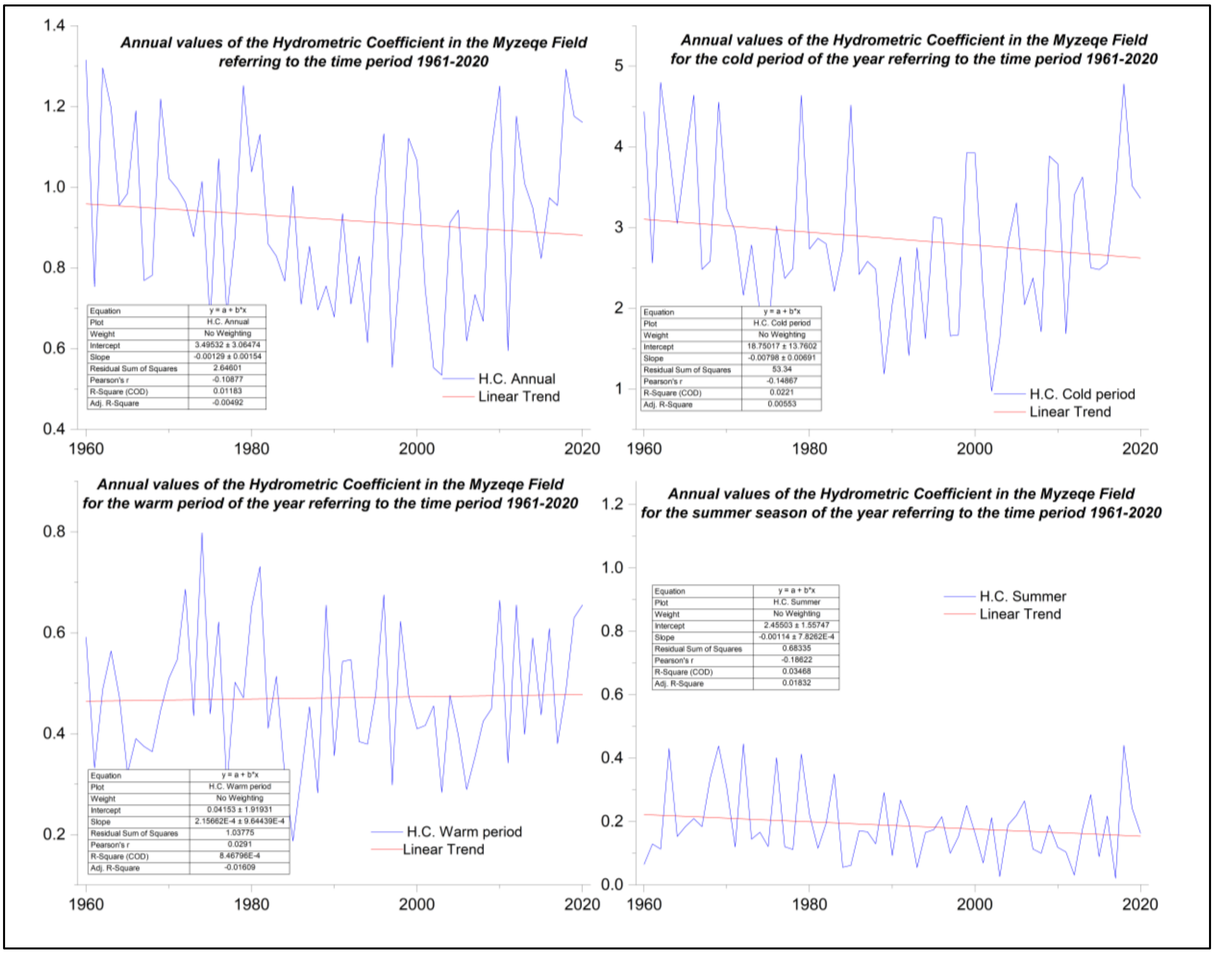

Fig. 3. Hydrothermal Coefficient values in the Myzeqe Plain (1961–2020): annual, cold, warm, and summer periods

This is due to the fact that in recent years an increase in situations with orographic precipitation has been observed, which are concentrated during the warm months (G. Çela et al., 2025). The declining trend of the Hydrothermal Coefficient is also observed during the cold period of the year. Although this season is not typically characterized by drought conditions, its scientific relevance lies in revealing the effects of changes in the precipitation and temperature regimes. During the summer season, the values of the Hydrothermal Coefficient drop below 0.2, reaching thresholds that correspond to extreme drought conditions. Dry years are more pronounced particularly during the second climate normal period (1991–2020).

The scientific assessment of agricultural droughts in the Myzeqe Plain also includes the analysis of SPI and SPEI indicators at a 3-month level, focusing only on the warm period of the year, April-September. This aims to assess the intensity and frequency of agricultural droughts during the most critical season for the development of agricultural crops in the Mediterranean climate. SPI-3 (Standardized Precipitation Index) provides an assessment of drought based only on precipitation, while SPEI-3 (Standardized Precipitation Evapotranspiration Index) also takes into account potential evaporation, reflecting the impact of high temperatures on the water balance. By analyzing the entire 60-year period, the study enables the identification of changes over time in drought dynamics and helps in assessing the potential impacts of climate change on agriculture. Both indicators, through standardized monthly values, provide a clear picture of extreme deviations from the average and allow the construction of maps and time series that highlight long-term trends and the most pronounced drought episodes.

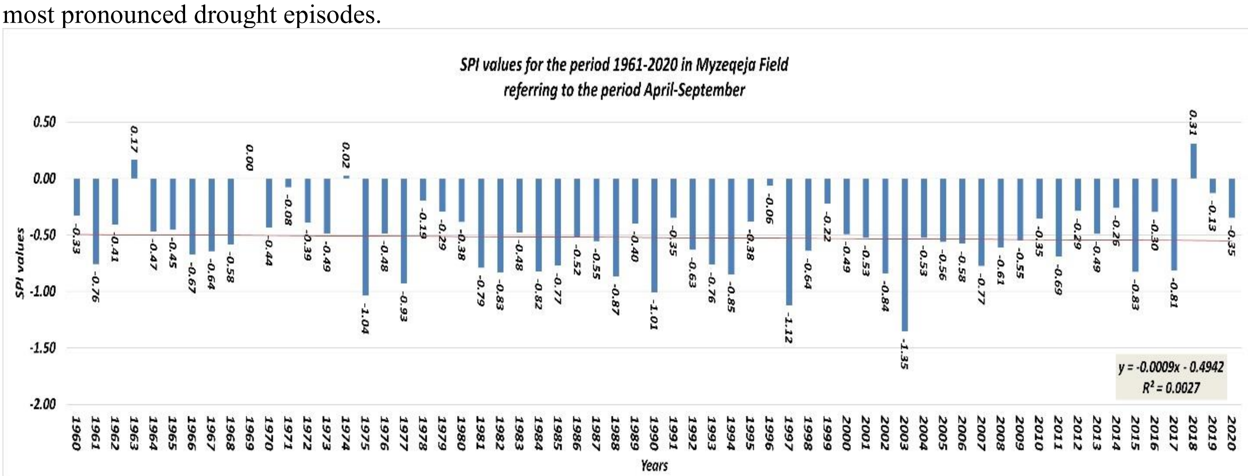

Fig. 4. Annual values of the 3-month SPI referred to the April-September season for the years 1961-2020

Despite several years with relatively favorable conditions, the long-term trend of the average SPI-3 values for this season shows a slight downward trend, suggesting that the frequency of short-term droughts during the warm season has been increasing, especially after the 1990s. The years with the most negative values are 1975, 1997 and 2003. This finding is consistent with climate projections for the Mediterranean region, where a decrease in seasonal precipitation and an increase in dry intervals during the warm seasons are expected (Legg, 2021).

In a more detailed assessment and with scientific results with added practical value, the analysis of the SPEI indicator serves. Through Figure No. 5, the analysis of the SPI and SPEI indicators combined together is presented in graphical form. The graph presents the interannual variability of the standardized precipitation index (SPI-3) and the precipitation and temperature index (SPEI-3) for the critical agricultural period April–September during the years 1961–2020 in the study area. Both indicators have been calculated at a 3-month level to reflect the seasonal impact of drought on agricultural ecosystems, in accordance with the recommendations of the literature for the Mediterranean climate(Vicente-Serrano et al., 2010). The yellow color under SPI-3 indicates periods of relative drought, while the blue and red lines represent the performance of SPEI-3 and SPI-3, respectively. These lines reflect different drought dynamics depending on whether or not temperature is included in the calculation. The trend lines show a downward trend for both indicators, but only SPEI-3 has a statistically more significant trend (Slope = -0.0142; $R^2 = 0.15$), compared to SPI-3 which has an almost statistically insignificant trend (Slope = -0.0009; $R^2 \approx 0$).

This difference highlights the increasing role of temperatures and potential evaporation (PET) in intensifying agricultural drought over recent decades. After 1990, SPEI-3 reflects more than SPI-3 the deepening of seasonal drought, indicating that the impact of extreme temperatures has increased significantly compared to previous decades.

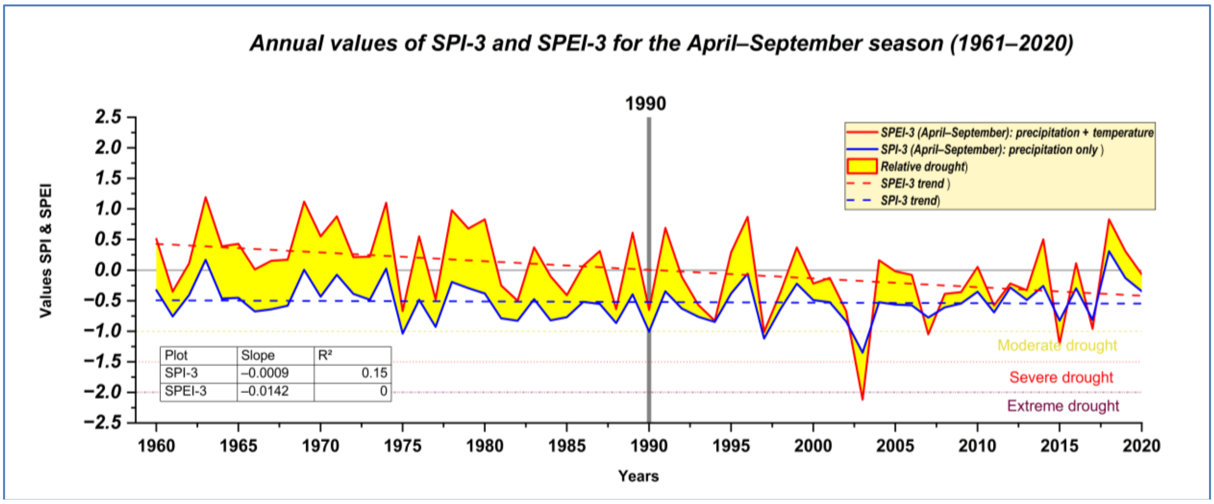

Fig. 5. Annual values of SPI and SPEI for the April-September season during the years 1961-2020 in the Myzeqe Plain.

The stratification of drought classification (with horizontal lines) according to SPI/SPEI thresholds (–1.0, –1.5, –2.0) helps in the visual identification of years with moderate, severe and extreme drought, as defined by the World Meteorological Organization(Svoboda, Hayes, & Wood, 2012). Years such as 1990, 2003 and 2012 show SPI-3 and SPEI-3 values that fall below –1.5, being classified as years with severe or extreme drought. In certain years the SPI and SPEI values are above the threshold of 0, these time segments which do not present a significant concern are categorized as normal years without significant drought.

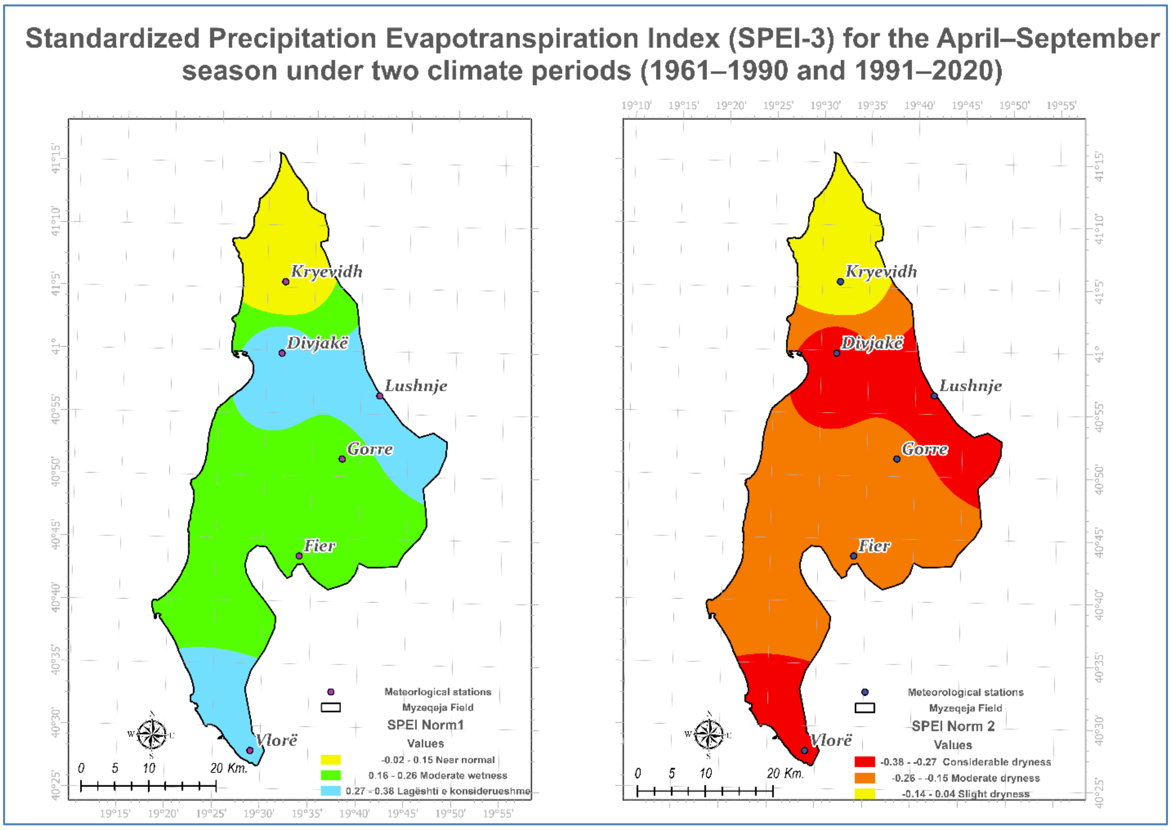

Fig. 6. Geographic distribution of the SPEI3 indicator in the Myzeqe Plain during the two climate norms 1961-1990 & 1991-2020 for the April-September season.

In conclusion, this graph supports the analysis that SPEI is a more sensitive and representative indicator for assessing agricultural drought in periods with significant temperature impact, while SPI may underestimate the intensity of drought, especially after 1990.

The map shown in Figure No. 6 represents the spatial changes of the standardized precipitation index with potential evaporation (SPEI-3) during the April–September agricultural season, for two climatic periods: 1961–1990 (Norm 1) and 1991–2020 (Norm 2), in the Myzeqe Plain region. In Norm 1 (1961–1990), the area is characterized mainly by normal to moderately humid conditions, with SPEI-3 values ranging up to +0.38. The highest humidity is observed in the southern part (Vlora, Gorre), while the northern part of the area (Kryevidh, Divjakë) maintains a regime closer to normal. This distribution signals that during this period seasonal drought was not a dominant concern, and the presence of sufficient moisture to support vegetation cycles was widespread throughout the area. In clear contrast, in Norm 2 (1991–2020) a significant deterioration of humidity conditions is observed. SPEI-3 for this period shows low values reaching up to –0.38, signaling a significant increase in seasonal drought. Most of the area, including Divjaka, Fier, Vlora and Gorren, is classified as significant to moderate drought. Only the northernmost part (Kryevidh) maintains a slightly milder drought condition. This deterioration suggests the impact of increasing temperatures and decreasing effective precipitation during the warm season, in line with climate trends reported in Mediterranean regions.

This transition from wet to dry between the two periods confirms the impact of climate warming in intensifying agricultural drought, especially during the April–September season that coincides with the most sensitive phases of vegetation growth. Similar decreases in SPEI have been documented in the scientific literature for Mediterranean areas, where the combination of reduced precipitation and increased potential evaporation (PET) causes a decrease in the soil water balance(Vicente-Serrano et al., 2010).

IV. CONCLUSION

The assessment of agricultural droughts is part of genuine scientific studies in the efforts to assess agro-climatic conditions in the Myzeqe Plain. This study provides a comprehensive assessment of meteorological and agricultural droughts through the analysis of various climatic indicators, including the duration without precipitation. The Hydrothermal Coefficient according to Selyaninov (KH), as well as the SPI and SPEI indices at 1-, 3- and 6-month levels. The results show a clear trend towards the intensification of dry periods, especially after 1990, which coincides with the second climatic period (1991–2020).

The uninterrupted duration of days without precipitation in the summer season is reflected in the second climatic norm with an average of 2 more days. Although from a physical-geographical point of view the Myzeqe Plain is a uniform territory, local precipitation brings a variety of micro-climatic conditions. In parallel, the Hydrothermal Coefficient over the 60 years marked decreasing values with obvious trends of drought severity, especially in the summer season where values reach below 0.2 at the desert borders.

The SPI and SPEI indicators were analyzed on a 3-month basis, emphasizing the warm period of the year April-September. The results were presented through a special graph that reflects the progress over the 60 years of drought, where in certain years the SPEI values reach below the -1.5 threshold, representing extremes and multi-year downward trends. Also, through a map, the values of the same time range of SPEI for the two climate norms are presented. Through this map, the geographical distribution of SPEI is evidenced as a phenomenon with a noticeable worsening trend over the last 30 years.

In conclusion, the integration of different indicators such as SPI, SPEI, Days without Rain and KH provides a powerful framework for monitoring and assessing droughts. The findings highlight the need for climate adaptation policies and improved early warning systems for the agricultural sector, with the aim of minimizing the impacts of droughts on agricultural production and food security.

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