

FLUCTUATIONS OF THE AGROCLIMATIC CONDITIONS FOR THE DEVELOPMENT OF VITICULTURE IN A CERTAIN VITICULTURAL REGION ON THE BASIS OF LAND DATA

Plamen Lakov

University of Agribusiness and Rural Development

Abstract

In recent decades, global warming has affected the development of agriculture, including viticulture. Winegrowers and winemakers must consider the fluctuations of the climatic elements now and in the future. Proceeding from these positions, the author considers that the topic of agroclimatic conditions for the development of the grapevine is relevant in view of the possibilities for producing quality grapes and wine.

The main aim of the study is to investigate some of the main agroclimatic indicators for grapevine development, related to precipitation and its fluctuations for different periods of time, such as: annual precipitation amount, Selyaninov hydrothermal coefficient for June, July and August, precipitation amounts for September and October, precipitation amounts above 110 mm for September and October and their frequency in a certain geographical region, namely: the region of Knezha, Pleven and Pavlikeni.

The analysis is based on a baseline period of 50 years: 1931–1980. Regarding the fluctuations of the indicators related to the base period, 30-year series were formed for the periods 1981–2010 and 1989–2019. Relevant findings, summaries and conclusions have been drawn.

Key words: climate, viticulture, agroclimatic indicators, precipitation, fluctuations

1. Introduction⁴

In recent decades, the global warming of the Earth affects the development of agriculture, including viticulture. People and their decisions have a key role in building a climate-resilient agricultural system. Winegrowers and winemakers must consider the fluctuations of the climatic elements now and in the future.

Proceeding from these positions, the author considers that the topic of agroclimatic conditions for the development of the grapevine is relevant in view of the possibilities for producing quality grapes and wine, including the region of Knezha, Pleven and Pavlikeni. The city of Pleven and its surroundings have been known since ancient times as a place of quality wine production. The city is also home to the Institute of Viticulture and Enology, the scientific research center of Bulgaria.

In the present study, the author aims to investigate some of the main agroclimatic indicators for grapevine development related to precipitation and its fluctuations over different periods of time.

⁴ This publication was prepared under INVEST FOR EXCELLENCE IN REGIONAL SUSTAINABILITY (INVEST4EXCELLENCE) project. The project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101035815. Responsibility for the information and views set out in this paper lies entirely with the authors.

2. Theoretical Basis of the Study

To define a *climate system*, the following formulation is adopted: „chronologically, the climate system is determined but chaotic due to its strong sensitivity to initial conditions, nearly intrasitive with complex aperiodic behavior and limited predictability“, **the impermanence of the system is its attribute**. By definition, “*climate* is an abstract concept described by the characteristics of meteorological elements averaged over a particular time interval over a planetary or a defined local spatial range”, „the substantial carrier of the climate is the atmosphere, together with the contact surface of the system components: hydrosphere, lithosphere, cryosphere and biosphere”⁵.

The main climate-forming factors are solar radiation, atmospheric circulation and the underlying surface.

In this regard, the empirical research approach for the region of Knezha, Pleven and Pavlikeni provides a statistical description of the „history” of the climate.

The main agroclimatic indicators for grapevine development are as follows:

1. Average starting date of sustained air temperature retention above 10°C.
2. Average end date of sustained air temperature retention above 10°C.
3. Duration of sustained air temperature retention above 10°C, in days.
4. The sum of the air temperature collected during the period with stable retention of the air temperature above 10°C and its provision.
5. Average daily temperature of the warmest month.
6. Last spring and first autumn frost and average duration of frost-free time.
7. Annual amount of precipitation.
8. Hydrothermal coefficient of Selyaninov – kSel – for June, July and August.
9. Precipitation amounts for September and October.
10. Precipitation amounts above 110 mm for September and October and their frequency.⁶

This publication examines the indicators related to precipitation.

3. Methods

The application of statistical-mathematical methods is determined by the need to process the available meteorological information and obtain statistically uniform climatic series. Violation of the statistical series is very often connected with a shuffling of the location of the respective station. In accordance with the existing tradition in climatology, the relationship between the meteorological values at the neighbouring stations is analysed. It should be emphasised that in the case of precipitation the variability of the element is not only due to methodological reasons but also to the natural variability of atmospheric processes.

For the period 1981–2019, the relationship method was used to recover the monthly and annual meteorological data. A basic requirement for parameter estimation is consistency, immutability and efficiency. Statistical parameters such as norm (mean), mean squared deviation, coefficient of variation, mean error, median, empirical and theoretical safety curve, etc. are calculated. The following formula is used to determine the total probability P%: $P=(m-$

⁵ Topliyski, D. Chronological Fluctuations of the Climate in Bulgaria in the 20th century. PhD Thesis, CY St. Kliment Ohridski University of Sofia, Faculty of Geology and Geography, 2005 (in Bulgarian)

⁶ Zoning of Viticulture in Bulgaria, Scientific works, Volume III, Zemizdat, S., 1960 (in Bulgarian)

$0.3/n+0.4$).100, where m is the sequence number of the member in the descending series, n is the number of years (or observations) in the series.

Conformity between the source data and the accepted type of theoretical distribution, the normal Gaussian distribution, is established by a correlation coefficient, in other words, χ^2 - Pearson criterion. To establish the significance of the differences, in the fluctuations of the individual elements for different periods, the Studen t-test for independent samples was applied. The nonparametric Shapiro–Wilk test was also applied (see Table 7, Annex 3).

Comparative analytical analysis was applied to identify the main similarities and differences in the territorial distribution and precipitation patterns.

The need for a spatial presentation of the study results necessitates the use of the cartographic method used to determine the territorial extent of the stations. When creating the maps, the corresponding generalisation has been done.

In the territorial presentation of the precipitation, the Thiessen method, or the method of polygons with equal precipitation (the polygon method) was applied. A 1:1000000 scale map of Bulgaria of the reference meteorological and agro-meteorological stations, rain gauge and phenological stations, issued by the Chamber of Engineers in Investment Design, Cartography Office, in 1978, was used as a map basis. On the map, a network of polygons is built, formed in a graphic way by all neighbouring Kneža, Pleven and Pavlikeni stations. This creates a polygon around each station, the area of which is measured⁷. The average precipitation for each station is taken as the average of its entire polygonal area.

The polygon for the Knezha is formed by the created network of the neighboring stations: Ostrov, Orehovitsa, Koynare, Chomakovtsi, Borovan. For Pleven, these are the stations Podem, Mechka, Slavyanovo, Pordim, Vladinya, Slatina, Nikolaevo, Krushovitsa, Dolni Dabnik. For Pavlikeni, the neighboring stations are Karaisen, Dolna Lipnitsa, Resen, Balvan, Suhindol, Alexandrovo and Levski.

The method is accurate when there are enough stations and in flat terrain, which is the current case.

The polygons obtained around the stations Knezha, Pleven and Pavlikeni by the method of interpolation (for clarity) are mapped on a topographic map at a scale of 1:50 000. The maps are subjected to additional computer processing, where the graphic method and the qualitative background method are applied. The author has accepted the precipitation as a territorial limiting factor of the survey, i.e. the territorial extent of precipitation coincides with the spatial extent of the survey (see Annex 1, *Figures 2 and 3*).

The analysis is based on a baseline period of 50 years: 1931–1980. Regarding the fluctuations of the indicators related to the base period, 30-year series were formed for the periods 1981–2010 and 1989–2019. The results are compared with those published in *Zoning of Viticulture in Bulgaria*, Volume III (Sofia: Zemizdat, 1960) and other publications, on the basis of which the relevant conclusions, findings and generalizations are made.

4. Territorial Scope

The determination of the territorial scope is one of the main tasks of this study. In its decision, several factors limiting this scope are taken into account. First of all, it is the location of

⁷ Lakov, Pl. The Climate of Central Northern Bulgaria (PhD Thesis). VT, 2006

the stations that provide the necessary data for the study: *Knezha*, *Pleven* and *Pavlikeni*. They are located in parts of the Western and Middle Danube Plain. Their geographic coordinates are given in *Table 1*. In the second place, the application of the already reviewed Thyssen polygon method, with which we report territorial precipitation by stations.

Table 1. Geographical coordinates of the studied stations

Station	Altitude above sea level (m)	East longitude: λ	North latitude: φ
Knezha	120	24°05′	43°20′
Pleven	130	24°36′	43°25′
Pavlikeni	133	25°18′	43°14′

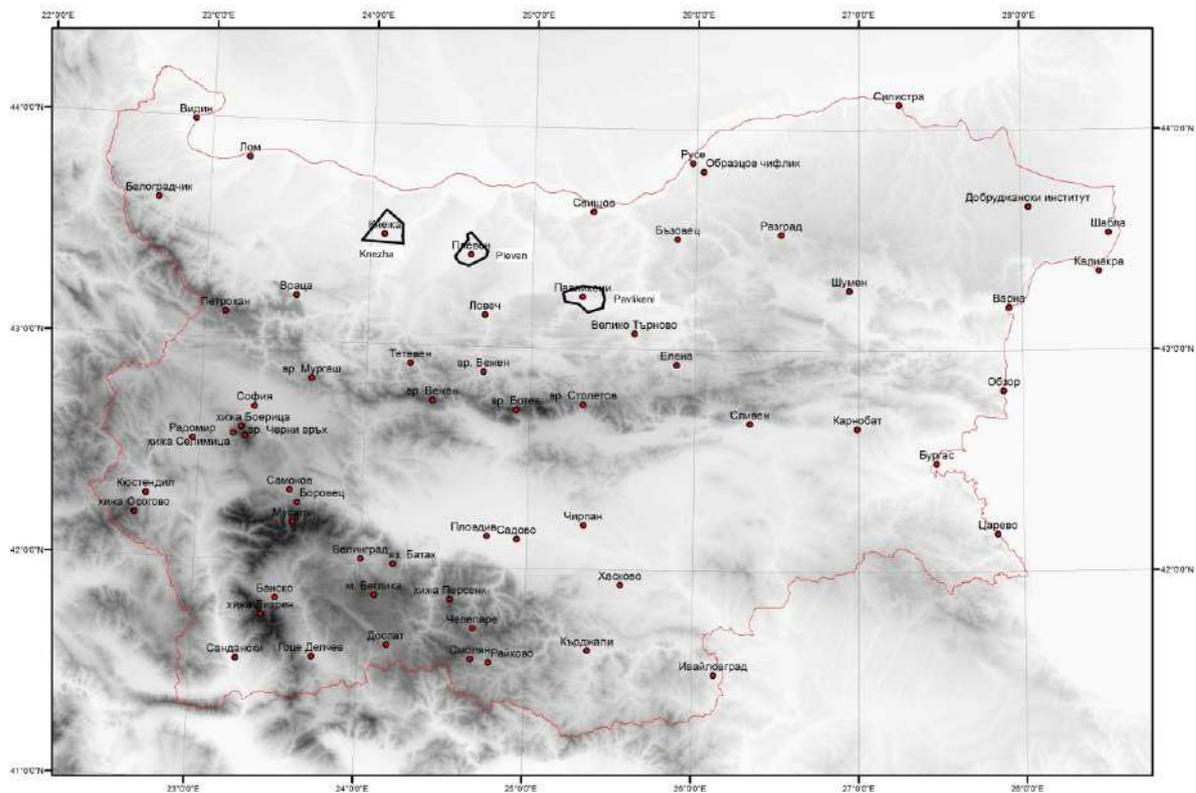


Figure 1. Map of the Republic of Bulgaria and the region of Knezha, Pleven and Pavlikeni

The westernmost station is *Knezha* (Annex 1, *Figure 2*), and the total area is estimated to be approximately 712 km².

Pleven station covers an area of about 455km² (Annex 1, *Figure 2*).

The easternmost station is *Pavlikeni* (Annex 1, *Figure 3*). The total area is estimated at about 418 km².

The area concerned includes the territories of the three stations and extends approximately between 43°09′ (Vishovgrad) and 43°39′ (between Selanovtsi and Knezha) north latitude, and

between 23°51'30'' (Sokolare) and 25°26' (Lesicheri) east longitude, and the total area is 1585 km² (see *Figure 1*).

5. Results of the Study

5.1. Precipitation characteristics in the region of Knezha, Pleven and Pavlikeni

The precipitation is determined by the transfer of air masses, by the processes that objectively take place in the atmosphere, and by the character of the relief. Most of the precipitation in Knezha, Pleven and Pavlikeni falls on atmospheric fronts. Another part falls from the so-called intra-mass cloudiness.

Average annual amount of precipitation

Average annual precipitation is not evenly distributed. It depends not only on the atmospheric circulation, but also on the local features of the relief. Despite the region's relatively small size and the fact that it falls entirely in the temperate-continental climate area, there are certain fluctuations in the annual precipitation. In general, the region falls within the precipitation area of the Middle Danube Plain, which is part of Central Northern Bulgaria⁸. In the westernmost part of the region, the station of Knezha, the precipitation is about 580 mm. The precipitation in Pleven is also within 580 mm (*Annex 2, Table 2*). A larger amount annually falls at Pavlikeni station, where it exceeds 600 mm.

The degree of humidity gives important practical value to climatological knowledge. Selyaninov's hydrothermal coefficient is among the integral indices by which humidity conditions are determined. It is one of the agroclimatic indicators for the development of the grapevine, determining the humidification conditions. It is calculated according to the formula $kSel = P \cdot 10 / \sum T$, where P is the amount of precipitation in *mm* for the period with temperatures above +10°C; $\sum T$ is the temperature sum for the same period. When $kSel = 1-2$, the humidity conditions are good, at $kSel < 1$ the humidity is insufficient, and at $kSel > 2$ over-humidity occurs (see *Table 2*.)

Table 3. Scale for evaluating the humidification conditions according to kSel

$kSel \leq 0.5$	$0.6 \leq kSel \leq 1$	$1.1 \leq kSel \leq 1.5$	$1.6 \leq kSel \leq 2$	$kSel \geq 2$
Dry (semi-desert)	Arid (steppe zone)	Moderately humid (no dry period)	Humid (no dry period)	Very humid (over-humidity)

From the data obtained for Pleven and Pavlikeni, $kSel$ estimates the territory of the stations as dry for June, July and August. At Knezha station $kSel$ is 1.1, it is moderately humid there. In general, $kSel$ defines the territory of the region as one of those with insufficient moisture.

Precipitations in September and October are also important for the grapevine, especially levels above 110 mm. From the data presented in *Table 2* can be seen that for the period they did not exceed this amount. However, if we analyze the provision for the indicated months (*Figure 4*), for example for Pleven, it is clearly seen that the frequency of precipitation over 110 mm is 22–23%. In other words, the probability of such precipitation falling is about 2 times in 10 years.

⁸ XXX

Also of interest is the provision of precipitation over 110 mm per month, separately for September and October. In *Figure 5* and *Figure 6* the provision curve for Knezha station is presented. In this case, the provision is 5–6%. It is very rare that the precipitation exceeds 110 mm in September.

The situation for October is similar. The provision does not exceed 10%. Precipitation above 110 mm falls once every 10 years. When the amount of precipitation is total for the two months, then the probability increases. In *figure 7* it can be seen that the probability of heavy precipitation above 110 mm in the precipitation area of *station Knezha* exceeds the probability of *station Pleven*: the provision is already 35%, which means that 3 – 4 of 10 years may not be favorable for the development of the grapevine.

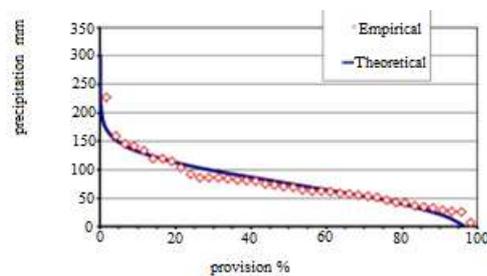


Figure 4

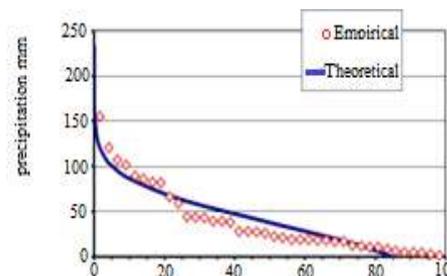


Figure 5

Figures 4 and 5. Precipitation provision of over 110 mm for the months of September and October for Pleven and Knezha for the period 1931–1980

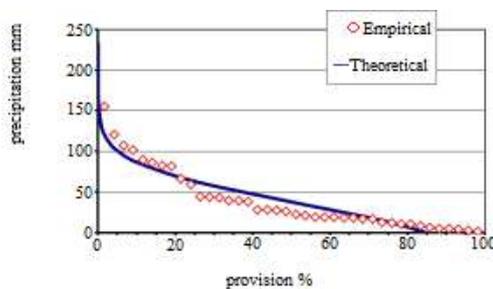


Figure 6

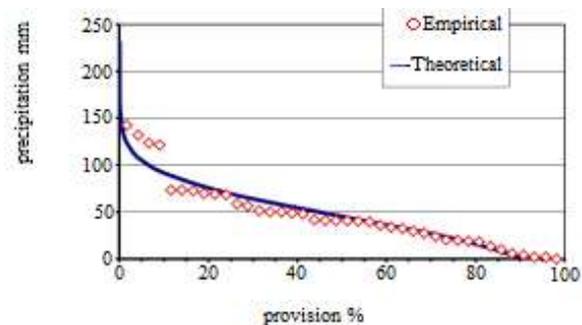


Figure 7

Figures 6 и 7. Precipitation provision of over 110 mm for the month of September and October for Knezha for the period 1931–1980

The situation is similar for October. The provision does not exceed 10%. Precipitation above 110 mm falls once every 10 years. When the amount of precipitation is total for the two months, then the probability increases. In *figure 8* it can be seen that the probability of heavy precipitation above 110 mm in the precipitation area of *station Knezha* exceeds the probability of *station Pleven*: the provision is already 35%, which means that 3 – 4 of 10 years may not be favorable for the development of the grapevine.

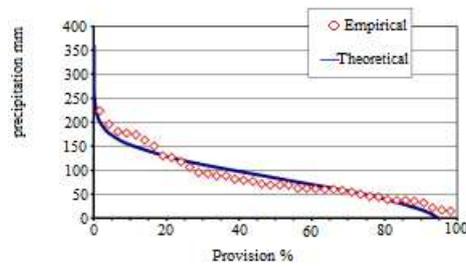


Figure 8

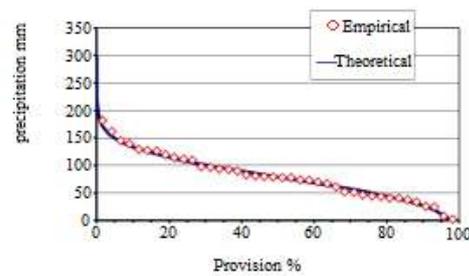


Figure 9

Figures 8 и 9. Precipitation provision of over 110 mm for the month of September and October for Knezha and Pavlikeni for the period 1931–1980

For *Pavlikeni station*, the probability of precipitation exceeding 110 mm in September and October increases.

Figure 9 shows the provision of *Pavlikeni station* and it is similar to that of *Knezha*: 30%.

5.2. Precipitation fluctuations in the region of Knezha, Pleven and Pavlikeni

Precipitation fluctuations in the region of Knezha, Pleven and Pavlikeni

There are a number of problems in establishing fluctuations in the precipitation pattern and amount. For the region, the baseline 50-year period 1931–1980 is related to two 30-year periods: 1981–2010 and 1990–2019. When processing the source data, already known findings were confirmed. Monthly precipitation by station deviates from a theoretical normal distribution as determined by the coefficients of variation, skewness, and kurtosis and their errors. The fluctuations (differences) in monthly and annual precipitation are characterized by the lack of statistically reliable periodicity and are random. The median (50% provision) of monthly precipitation gives a more reliable representation of the precipitation than the average for each period. In this regard, in addition to the mean, the basic statistics also present the root mean square deviation, the error of the mean, the median and the coefficient of variation. The resulting differences compared to the 50-year period were evaluated by Student t-test. Precipitation fluctuations are also represented by Selyaninov's hydrothermal coefficient for the summer months. Through it, the humidification conditions and the fluctuations resulting from the changes not only in the precipitation, but also in the air temperature are established (*Tables 4 and 5, Annex 2*). The precipitation for September and October and their provision for the different periods, which is a key agroclimatic indicator for the grapevine, are also considered.

In the precipitation zone of Knezha, Pleven and Pavlikeni, the annual sum of precipitations for the period 1931–1980 is between 570 and 620 mm, respectively. When compared with the period 1981–2010, an ambiguous fluctuation is found (*Figure 10*). For Knezha and Pavlikeni, the amount decreased by 42 and 80 mm, respectively.

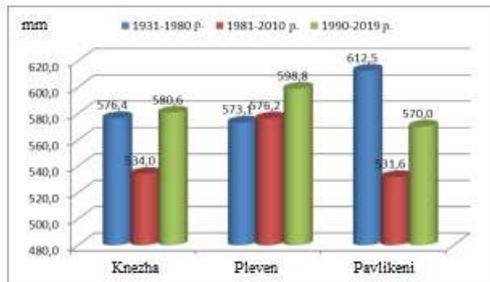


Figure.10

Figure 10. Annual amount of precipitation for different periods

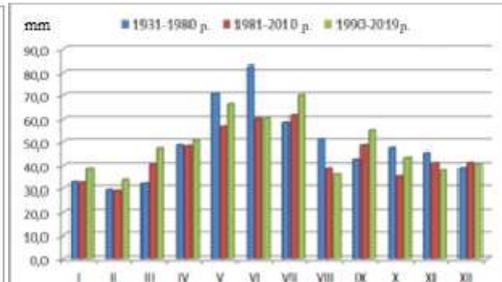


Figure 11

Figure 11. Monthly precipitation for different periods for Knezha station

However, the opposite trend is reported for Pleven. Only for *Pavlikeni station* the estimation of the difference is statistically significant. The fluctuation for the remaining stations is random. The decrease in the annual amount is due to lower precipitation in the spring-summer months for Knezha, and for Pavlikeni less precipitation fell in 9 out of 12 months of the year, i.e. in all seasons, but the decrease is best expressed in July (*Figures 11, 12 and 13*).

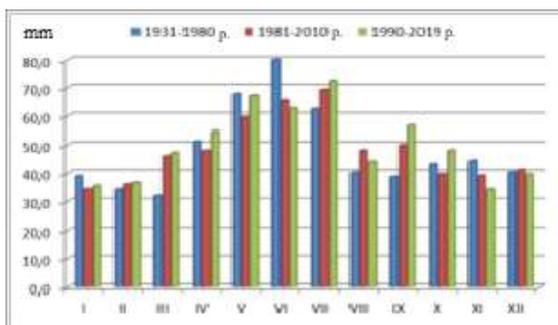


Figure12

Figure 12. Monthly precipitation for different periods for Pleven station

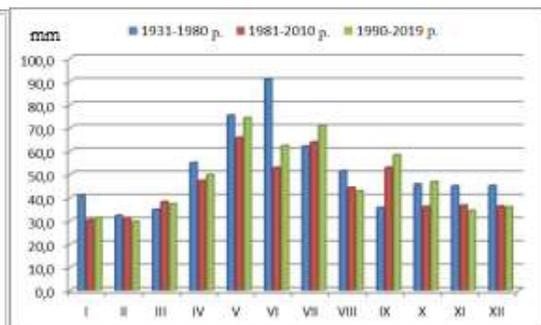


Figure13

Figure 13. Monthly precipitation for different periods for Pavlikeni station

For the period 1990–1919, fluctuations in the region show interesting trends (see *Figure 11., 12. и 13.*). In Pleven, the annual precipitation amount continues to increase and it is already around 600 mm. This is due to increased precipitation in March and from July to October. Changes are random. The increase in the amount of precipitation for September is non-random and statistically significant: $T > 1,69$. The decrease in precipitation in June is non-random, as well.

In the area of the Pavlikeni station, the trend of decreasing precipitation continues, reaching 570 mm. For September, however, an increase in precipitation was also observed in Pavlikeni. The 95% probability significance assessment shows that the increase is statistically significant and non-random.

For Knezha, a trend opposite to the previous period was found. The annual precipitations have increased and have effectively returned to the 1931–1980 precipitation amount of 580 mm. The fluctuations are random and statistically insignificant. More significant is an increase in the amount of precipitation in September.

For both thirty-year periods, in all three stations, a general decrease in precipitation was found in April, May, June, and an increase in precipitation in September. Estimates of significance fluctuate. For Knezha station in the first period the change is non-random, for Pavlikeni in both periods it is non-random, for Pleven it is however random, in other words there is an ambiguous assessment of the change (*Table 6, Annex 2*).

Of interest is the fluctuation of the annual precipitation amount for the entire studied period 1931–2019.

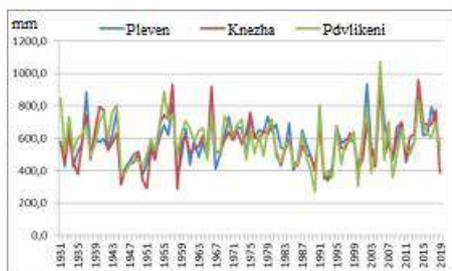


Figure 14

Figure 14. Annual precipitation amount per station for the period 1931–2019

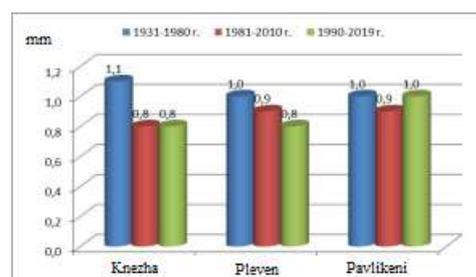


Figure 15

Figure 15. Selyaninov hydrothermal coefficient (VI–VIII) for different periods

From *Figure 14*, “cycles” towards a decrease and “cycles” towards an increase in precipitation can be visually determined. Synchronicity and periodicity cannot be determined. The trends are divergent and statistically unreliable.

Fluctuations of Selyaninov hydrothermal coefficient and precipitation in September and October in Knezha, Pleven and Pavlikeni

An interesting aspect of precipitation fluctuations is the Selyaninov hydrothermal coefficient for months VI–VIII (*Figure 15*).

For both periods, a decrease in kSel is observed, i.e. the territory of Knezha, Pleven and Pavlikeni becomes more arid. In all three stations, the index is between 0.8 and 1: arid, steppe zone. This is due to the statistically significant increase in air temperature during the summer months and the decrease in precipitation during the spring-summer period, best expressed mainly in June.

The fluctuations in the precipitations in September and October and above all those exceeding 110 mm are also essential for the development of the grapevine. From the data in the table, it can be seen that there is no significant change in the total amount for the period 1981–2010 compared to the 50-year period (*Figure 15*).

For the period 1990–2019, the data clearly shows the increase in this amount of precipitation, but even during this period, the multiannual precipitation amount does not exceed 110 mm.

On the other hand, however, the provision of precipitation amounts above 110 mm for the indicated months per station presents an interesting trend.

For Knezha (*Figure 16*) the probability of precipitation exceeding 110 mm for the period 1981–2010 is 30%, or during 3 of every 10 years the event may occur.

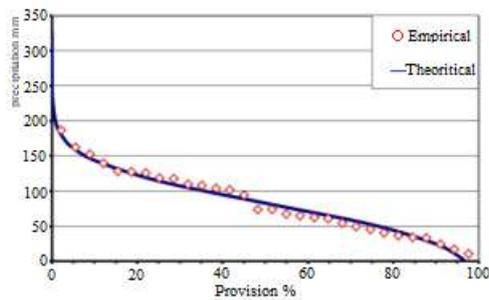


Figure16

Figure 16. Provision of precipitation over 110 mm, September and October, for the period 1981–2010, for Knezha station

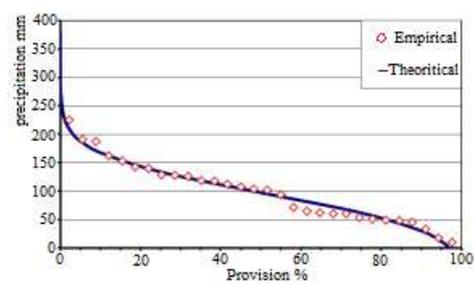


Figure17

Figure 17. Provision of precipitation over 110 mm, September and October, for the period 1990–2019, for Knezha station

For the period 1990–2019, the probability is already 42–43% (*Figure 15*). Every ten years, for 4 of them, the rainy conditions in September and October can be unfavorable for the development of the grapevine.

For Pleven station, the agroclimatic conditions are similar. For the period 1981–2010, the probability of precipitation exceeding 110 mm is 37–38% (see *Figure 18*). Compared to the baseline period, a 15% increase in the probability of unfavorable precipitation for the grapevine was found.

Current precipitation conditions for Pleven station show a persistent trend towards an increasing probability of precipitation above 110 mm. For the period 1990–2019, the provision is about 45%. This can be determined very well visually from *Figure 19*.

For Pavlikeni station, the probability of precipitation exceeding 110 mm for the period 1981–2010 is 37–38%. It has to be concluded that also in the precipitation area of Pavlikeni, the probability of unfavorable precipitations for the grapevines in September and October has increased. (see *Figure 20*)

For the period 1990–2019, the probability of precipitation above 110 mm for Pavlikeni is similar to that of Pleven and is about 45%. (see *Figure 21*)

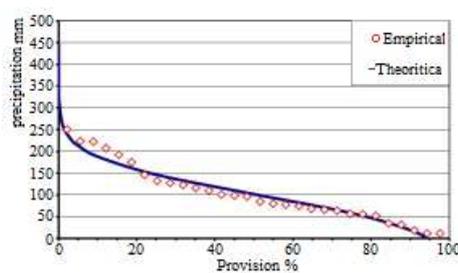


Figure18

Figure 18. Provision of precipitation over 110 mm, September and October, for the period 1981–2010, for Pleven station

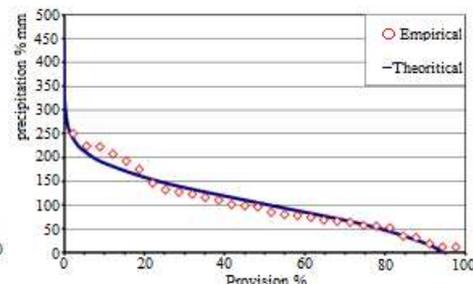


Figure19

Figure 19. Provision of precipitation over 110 mm, September and October, for the period 1990–2019, for Pleven station

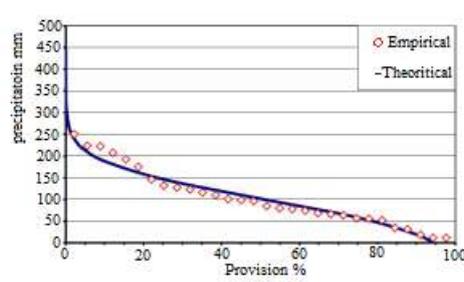


Figure 20

Figure 20. Provision of precipitation over 110 mm, September and October, for the period 1990–2019, for Pleven station

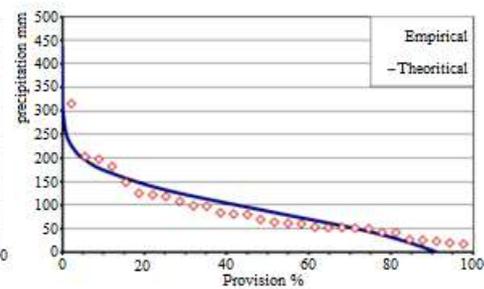


Figure 21

Figure 21. Provision of precipitation over 110 mm, September and October, for the period 1981–2010, for Pavlikeni station

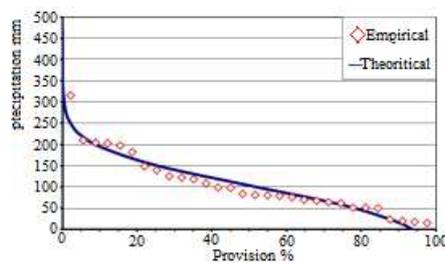


Figure 22

Figure 22. Provision of precipitation over 110 mm, September and October, for the period 1990–2019, for Pavlikeni station

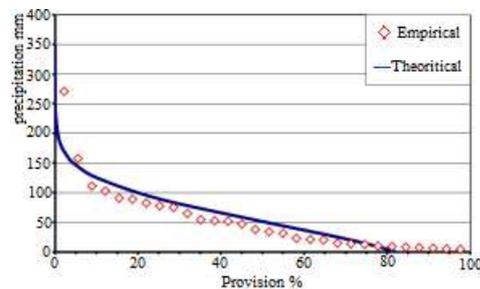


Figure 23

Figure 23. Provision of precipitation over 110 mm, September, for the period 1990–2019, for Pavlikeni station

Also of interest is the monthly presentation of the precipitation provision. For the sake of brevity, we will present the provision of Knezha, Pleven and Pavlikeni in September for the period 1990–2019, *Figures 23, 24 and 25*.

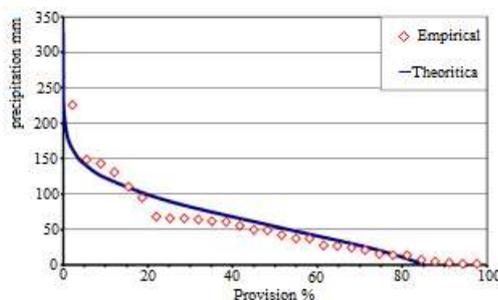


Figure 24

Figure 24. Provision of precipitation over 110 mm, September, for the period 1990–2019, for Pleven station

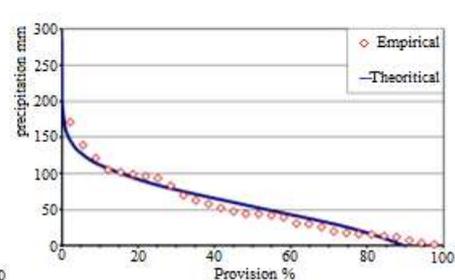


Figure 25

Figure 25. Provision of precipitation over 110 mm, September, for the period 1990–2019, for Knezha station

From the presented provision curves of precipitation amounts above 110 mm, it can be seen that the probability in September for Plevan is 15–17%, for Pavlikeni – 16–18%, and for Knezha – 14–15%. In other words, 1–2 of 10 years can be unfavorable for the grapevine. If we compare the obtained result with the provision of precipitation amounts above 110 mm, with the baseline period 1931–1980 for September, we will note a significant change. For Knezha, for example, the probability was 5%, in other words very small, and now it is already 15%. In the other stations the situation is similar. In September, the probability of precipitation exceeding 110 mm has increased.

6. Conclusions and Summaries about the Chronological Fluctuations of the Main Agroclimatic Indicators for the Development of the Grapevine, Related to Precipitation.

From the analysis presented, some **conclusions and summaries** can be drawn.

The analysis of the fluctuations in Knezha, Plevan and Pavlikeni leads to certain **conclusions**:

1. There is a lack of spatial synchronicity in the manifestation of precipitation fluctuations in mentioned stations during different periods.

2. Fluctuation of the annual precipitation amount is noted. However, it cannot be said to be statistically significant. We see both increases and decreases in precipitation amount, but in most cases it is random, characteristic of the climate system, particularly the precipitation.

3. A decrease in the amount of precipitation was observed in April, May and best expressed in June, as well as an increase in precipitation in September. In the majority of stations for June and September, the change is statistically significant and non-random.

4. The differences observed in most cases are random. The null hypothesis cannot be categorically rejected.

5. For both periods, a decrease in k_{sel} is observed, i.e. the territory of Knezha, Plevan and Pavlikeni becomes more arid. In all three stations, the index of the Selyaninov hydrothermal coefficient is between 0.8 and 1: arid, steppe zone. This is due to the statistically significant increase in air temperature during the summer months and the decrease in precipitation during the spring-summer period, best expressed in June.

6. Compared to the 50-year period, precipitation above 110 mm in the Knezha, Plevan and Pavlikeni region in September and October for the two thirty-year periods has no significant increase.

7. Compared to the 50-year period, the precipitation provision curve in Knezha, Plevan and Pavlikeni region for September and October for the two thirty-year periods shows a trend of a 10–15% increase in the probability of precipitation above 110 mm.

8. For the recent period 1990–2019, for 3–4 out of every 10 years, the precipitation may be unfavorable for grapevine development in September and October.

9. The higher probability of adverse precipitation for both 30-year periods is due to the observed (above) increase in September precipitations and the assumed increased intensity.

Bibliography:

1. AGROKLIMATICHESKOE rayonirovanie pyat osnovniih selskohozyaistveniikh kultur na territorii sotsialisticheskikh stran Evropii, opit intergalnoy selskohozyaistvennoy otsenki klimata territorii sotsialisticheskikh stran Evropii //BAN, Institut gidrologii i meteorologii, Sofiya, 1979.
2. AGROKLIMATICHEN atlas na Balgariya. – Sofiya: GUGK, 1982.

3. KARTA – Oporna hidrolozhka I hidrogeolozhka mreza v NRB, S. KIPP po kartografiya, 1977
4. KLIMATICHEN spravochnik za NR Balgariya: T. 3: Temperatura na vazduha, temperature na pochvata, slana. Pod red. na M. Kyuchukova. S.: Nauka i izkustvo, 1983. - 440 s.: s tabl.
5. KLIMATICHEN spravochnik: Intenzivni dazhdove v NR Balgariya. Pod red. na M. Kyuchukova, P. Ivanov, M. Sabeva. S.: BAN, 1986. - 272 s.: s tabl.
6. KLIMATICHEN spravochnik: Valezhi v Balgariya. Pod red. na M. Kyuchukova, P. Ivanov, M. Sabeva. S.: BAN, 1990. - 169 s.: s tabl.
7. KLIMATAT na Balgariya. Pod red. na Sv. Stanev, M. Kyuchukova, St. Lingova. S.: BAN
8. LAKOV, Pl. Klimatat v Tsentralna Severna Balgariya: (doktorska disertatsiya), VTU “Sv. sv. Kiril i Metodiy”, VT, 2006.
9. LAKOV, Pl. Klimatichen turisticheski potentsial na Zapadna i Sredna Severna Balgariya: Monografiya. Plovdiv, 2013, - 208 s.: s tabl., chert., k., diagr.
10. LAKOV, Pl. Klimatichna skitsa na Pleven i regiona// studiya, Pleven, 2018, sb. Miziya ot drevnostta do dnes, Tom I, izd. Regionalen istoricheski muzey – Pleven, str.159-219.
11. MESECHEN byuletin: Za 1992–2005. S.: NHMI, BAN.
12. METEOROLOGICHEN godishnik: za 1930–1981. S.: BAN, GUHM.
13. METEOROLOGICHEN mesechnik: za 1980–1984. S.: BAN, GUHM.
14. PETROV, V., G. Mikovski, Obshta teoriya na statistikata i agrarnata statistika // Svishtov: Ak. Izdatelstvo “Tsenov”, 1994.
15. PISARSKI, A. Sredizemnomorski tsikloni i vliyanieto im varhu vremeto u nas. // Hidrologiya i meteorologiya, 1955, № 5.-6.
16. RAYONIRANE na lozarstvoto v Balgariya, nauchni trudove, Tom III, Zemizdat, S., 1960, - 168 s.: s il. i k.
17. RAKOVODSTVO po klimatologiya: Za studentite ot VUZ/ B. Vekilska, D. Topliyski, G. Rachev, G. Gaydarova. – Sofiya: Universitetsko izdatelstvo “Sv. Kliment Ohridski”, 1992. – 171 s.: s tabl. i il.
18. SIRAKOV, D. Statisticheski metodi v meteorologiyata: Uchebnik za studentite ot Sofiyski universitet “Sv. Kliment Ohridski” / D. Sirakov. –Sofiya: SU, 1981, 1981. – 270 s.: s tabl. i diagr.
19. SKRINIK, O.A., A.I. Snizhko, Zadacha viznacheniya dati stiykogo peredhodu prizemnoy temperature povitrya cherez pevne fiksovane znachenna (analiz metodiv), Kievskiy natsionalniy universitet imeni Taras Shevchenko, UDK 551.583:551.588
20. TOPLIYSKI, D. Hronologichni kolebaniya na klimata v Balgariya prez XX vek. Doktorska disertatsiya, SU “Sv. Kliment Ohridski”, GGF, 2005.
21. HRISTOV, P. Prakticheskovo rakovodstvo za obrabotka na meteorologichni Danni: Ch. I – II/ P. Hristov. – Sofiya: HMS, 1975.
22. BLUTHGEN, J., Allgemeine klimageographia. Berlin, 196
23. LORENZ, E. The General Circulation of the Atmosphere. WMO, 1967.
24. LORENZ, E. The essence of chaos. Univ. of Washington Press, 1993.
25. www.stringmeteo.com
26. www.klimadia

27. www.ncdc.noaa.gov

28. www.meteo.bg

Annex 1



Figure 2 Territorial summary of precipitation at Knezha and Pleven stations using the polygon method (Thiessen method)⁹

⁹ Haygarov, Vanyo, P. Lakov, Agroclimatic conditions for viticulture and the production of quality grapevines and wines in Pleven and its region, Monograph, Academic Publishing House "Talent" of the Higher School of Agribusiness and Regional Development, Plovdiv, 2020, – 220 p.: with tables, graphs and maps (in Bulgarian)

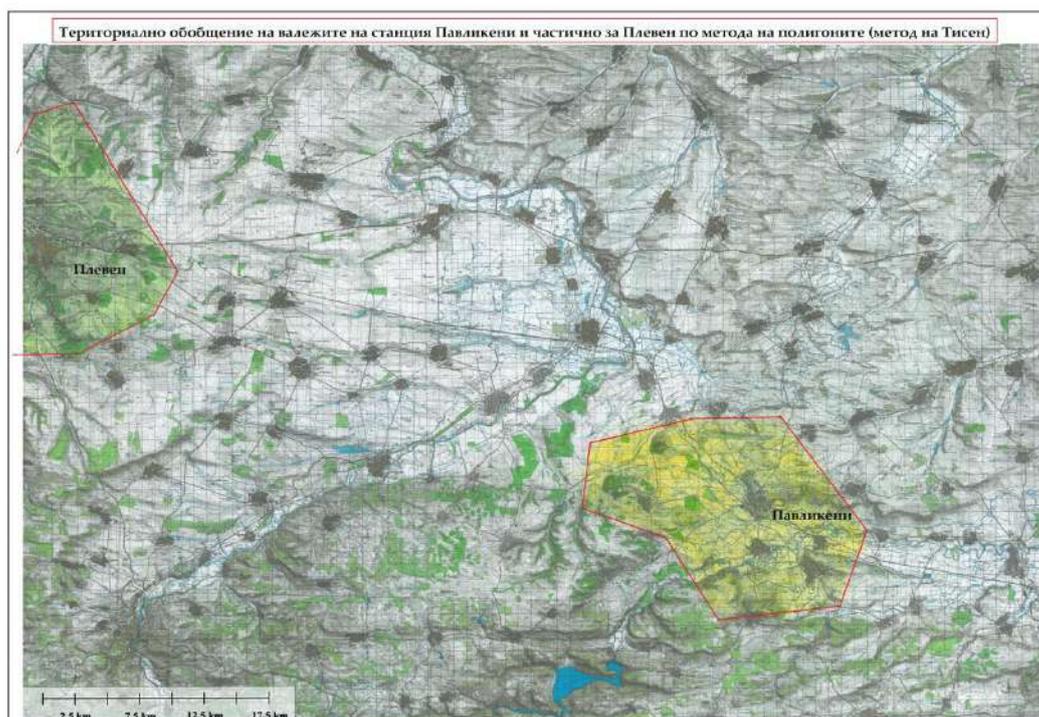


Figure 3 Territorial summary of precipitation at Pavlikeni stations using the polygon method (Thiessen method)¹⁰

Annex 2

Table 2. Basic statistics for the period 1931–1980. *X*: Monthly and annual amount of precipitation (in mm), *Me*: Median, *Sx*: Standard deviation, *Se*: Error of the mean, *Cv*: Coefficient of variations, *kSel*: Selyaninov's hydrothermal coefficient for months VI–VIII

Knezha															
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	IX+X	kSel
<i>X</i>	32,9	29,3	32,2	48,5	70,7	82,5	58,5	51,1	42,7	47,3	45,5	38,9	576,4	90,1	1,1
<i>Me</i>	29,5	27,3	27,7	44,0	62,6	77,4	54,5	35,8	26,0	40,9	39,3	37,6	585,0		
<i>Sx</i>	20,3	17,7	21,3	26,8	38,5	52,0	34,5	54,0	41,2	36,7	26,4	26,4	141,2		
<i>Se</i> %	8,7	8,5	9,4	7,8	7,7	8,9	8,4	14,9	13,6	11,0	8,2	9,6	3,5		
<i>Cv</i>	0,6	0,6	0,7	0,6	0,5	0,6	0,6	1	1,0	0,8	0,6	0,7	0,2		
Pleven															
<i>X</i>	38,9	34,2	31,9	51,2	67,7	80,0	62,4	40,2	38,7	43,2	44,4	40,3	573,1	81,9	1,0
<i>Me</i>	34,5	35,5	31,2	49,8	66,3	74,5	58,6	29,9	24,5	38,9	43,9	39,4	583,0		
<i>Sx</i>	21,6	17,8	18,9	29,4	36,1	40,1	32,9	35,1	35,6	34,1	22,7	24,9	122,0		

¹⁰ *Ibid.*

Se%	7,8	7,4	8,4	8,1	7,5	7,1	7,5	12,4	13,0	11,2	7,2	8,8	3,0		
Cv	0,6	0,5	0,6	0,6	0,5	0,5	0,5	0,9	0,9	0,8	0,5	0,6	0,2		
Pavlikeni															
X	40,7	32,2	34,7	54,8	75,3	90,8	61,9	51,3	35,5	45,6	44,9	45,0	612,5	81,2	1,0
Me	37,4	30,0	27,5	53,6	65,0	76,5	53,5	45,6	27,0	40,0	44,8	40,9	622,0		
Sx	21,4	19,4	22,1	29,0	40,6	54,2	39,5	36,0	32,5	33,8	25,2	28,9	123,0		
Se%	7,4	8,5	9,0	7,5	7,6	8,4	9,0	9,9	12,9	10,5	8,0	9,1	2,8		
Cv	0,5	0,6	0,6	0,5	0,5	0,6	0,6	0,7	0,9	0,4	0,6	0,6	0,2		

Table 4. Basic statistics for the period 1981–2010. *X: Monthly and annual amount of precipitation (in mm), Me: Median, Sx: Standard deviation, Se: Error of the mean, Cv: Coefficient of variations, kSel: Selyaninov's hydrothermal coefficient for months VI–VIII*

Knezha															
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	IX+X	kSel
X	32,6	28,9	40,6	48,1	56,7	60,3	61,8	38,8	48,5	35,4	41,1	41,3	534,0	83,9	0,8
Me	28,1	19,7	33,3	43,3	57,1	52,5	49,1	23,6	40,9	28,4	31,9	35,0	525,3		
Sx	22,1	19,4	21,6	25,7	28,3	39,3	49,7	39,8	37,3	29,7	29,6	25,6	126,5		
Se%	12,4	12,3	9,7	9,8	9,1	11,9	14,7	18,7	14,0	15,4	13,2	11,3	4,3		
Cv	0,86	0,68	0,82	0,90	1,01	0,87	0,79	0,61	0,84	0,80	0,77	0,85	0,98		
Pleven															
X	34,3	35,9	46,0	47,9	59,6	65,4	69,2	48,0	49,9	39,6	39,0	41,1	576,2	89,6	0,9
Me	24,2	30,0	38,0	46,4	59,9	62,0	58,5	32,5	37,0	37,0	31,8	40,8	568,5		
Sx	26,1	26,8	35,3	26,1	27,4	40,0	42,1	40,6	46,8	32,3	26,0	19,8	149,9		
Se%	13,9	13,6	14,0	10,0	8,4	11,2	11,1	15,4	17,1	14,9	12,2	8,8	4,7		
Cv	0,76	0,75	0,77	0,55	0,46	0,61	0,61	0,85	0,94	0,82	0,67	0,48	0,3		
Pavlikeni															
X	30,2	31,0	38,0	47,1	65,6	52,7	63,7	44,2	52,8	35,9	36,5	36,1	531,6	88,7	0,9
Me	21,8	27,0	31,8	43,5	55,1	52,0	44,3	30,4	36,0	35,4	30,0	35,0	490,0		
Sx	25,3	21,3	34,2	26,0	46,3	28,2	54,0	36,3	56,4	26,7	25,9	17,8	171,1		
Se%	15,3	12,5	16,4	10,1	12,9	9,8	15,5	15,0	19,5	13,6	13,0	9,0	5,9		
Cv	0,72	0,87	0,83	0,92	0,84	0,99	0,69	0,69	0,68	0,98	0,82	0,97	0,92		

Table 5. Basic statistics for the period 1990–2019. X: Monthly and annual amount of precipitation (in mm), Me: Median, Sx: Standard deviation, Se: Error of the mean, Cv: Coefficient of variations, kSel: Selyaninov's hydrothermal coefficient for months VI–VIII

Knezha															
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	IX+X	kSel
X	38,8	33,9	47,2	50,7	66,1	60,3	70,0	36,2	55,1	43,6	38,0	40,7	580,6	98,7	0,8
Me	34,4	35,8	36,1	48,4	72,9	52,9	52,1	23,6	44,0	44,0	32,4	34,1	592,3		
Sx	28,1	20,5	26,6	27,3	29,5	31,7	56,5	38,7	43,8	33,0	23,7	28,5	157,1		
Se%	13,2	11,1	10,3	9,8	8,1	9,6	14,7	19,5	14,5	13,8	11,4	12,8	4,9		
Cv	0,72	0,61	0,56	0,54	0,45	0,53	0,81	1,07	0,80	0,76	0,62	0,70	0,27		
Pleven															
X	35,5	36,6	47,3	54,6	67,2	62,6	72,3	44,1	56,7	48,1	34,2	39,6	598,8	104,7	0,8
Me	25,5	28,8	39,3	51,8	71,6	55,4	74,9	33,0	45,5	47,1	31,8	37,3	586,6		
Sx	30,8	27,2	34,2	31,7	31,2	34,9	45,4	37,7	51,3	35,5	20,0	23,5	156,4		
Se%	15,8	13,6	13,2	10,6	8,5	10,2	11,5	15,6	16,5	13,5	10,7	10,8	4,8		
Cv	0,87	0,74	0,72	0,58	0,46	0,56	0,63	0,86	0,91	0,74	0,59	0,59	0,3		
Pavlikeni															
X	31,2	29,5	37,1	49,7	74,2	62,2	70,8	42,6	58,2	46,7	34,2	35,8	570,0	104,9	1,0
Me	26,8	26,3	31,5	53,6	67,4	57,2	78,1	19,7	48,3	44,3	32,5	31,8	576,4		
Sx	20,7	21,6	25,1	23,6	45,5	35,5	53,3	38,4	58,1	33,2	21,1	21,1	177,0		
Se%	12,1	13,4	12,4	8,7	11,2	10,4	13,7	16,4	18,2	13,0	11,3	10,8	5,7		
Cv	0,66	0,73	0,68	0,48	0,61	0,57	0,75	0,90	1,00	0,71	0,62	0,59	0,31		

Table 6. Difference in precipitations between periods 1931–1981/1981–2010 г. (p1); 1990–2019 г. (p2) and significance assessment t-test: t1 of p1 and t2 of p2 (a „-“ sign on p indicates the amount of increase)

Knezha													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
p1	0,2	0,5	-8,4	0,5	14,0	22,1	-3,3	12,4	-5,8	12,0	4,4	-2,4	42,4
p2	-5,9	-4,6	-15,0	-2,2	4,6	22,1	-11,6	14,9	-12,4	3,8	7,4	-1,8	-4,2
t1	0,05	0,11	-1,68	0,08	1,71	1,99	-0,35	1,08	-0,62	1,49	0,67	-0,39	1,33
t2	-0,44	-0,46	-1,19	-0,17	0,30	1,28	-0,44	0,74	-0,58	0,23	0,63	-0,13	-0,06
Pleven													

p1	4,6	-1,7	-14,2	3,3	8,1	14,5	-6,8	-7,8	-11,2	3,6	5,4	-0,9	-3,1
p2	3,4	-2,3	-15,4	-3,4	0,6	17,3	-9,9	-3,9	-18,0	-4,8	10,2	0,6	-25,6
t1	0,84	-0,34	-2,30	0,49	1,05	1,55	-0,79	-0,90	-1,19	0,46	0,96	-0,16	-0,10
t2	0,58	-0,43	-2,19	-0,58	0,09	2,28	-1,12	-0,49	-1,80	-0,70	2,18	0,15	-0,83
Pavlikeni													
p1	10,5	1,2	-3,3	7,7	9,7	38,1	-1,8	7,1	-17,3	9,7	8,4	8,9	80,8
p2	9,5	2,7	-2,4	5,2	1,0	28,6	-8,9	8,7	-22,7	-1,1	10,7	9,2	42,4
t1	1,95	0,25	-0,52	1,18	0,96	3,52	-0,17	0,84	-1,71	1,33	1,40	1,50	2,42
t2	1,92	0,56	-0,45	0,82	0,10	2,54	-0,84	1,00	-2,21	-0,14	1,91	1,50	1,24

Table 7. Basic statistics of the main agroclimatic indicators for the grapevine: moisture conditions for different periods

Pleven									
period/ years	kSel VI-VIII	Annual amount, mm	Precipitations IX, mm	Precipitations over 110 mm, %	Precipitations X, mm	over 110 mm, %	Precipitations IX-X, mm	over 110 mm, %	
1915-1955	1	600	-	-	-	-	90	27	
1931-1970	0,9	556	34	2,5	43	5,0	77	20	
1981-2010	0,9	576	50	9,7	40	3,2	90	22,6	
1990-2019	0,8	599	57	12,9	44	3,2	105	35,5	
Knezha									
period / years	kSel VI-VIII	Annual amount, mm	Precipitations IX, mm	Precipitations over 110 mm, %	Precipitations X, mm	over 110 mm, %	Precipitations IX-X, mm	Over 110 mm, %	
1915-1955	1	547	-	-	-	-	91	-	
1931-1970	0,9	561	39	5,0	46	10,0	85	25	
1981-2010	0,8	534	49	6,4	35	0,0	84	29	
1990-2019	0,8	581	55	9,7	44	0,0	99	41,9	
Pavlikeni									
period / years	kSel VI-VIII	Annual amount, mm	Precipitations IX, mm	Precipitations over 110 mm, %	recipitations X, mm	ver 110 mm, %	Precipitations IX-X, mm	Over 110 mm, %	

1915–1955	1	594	-	-	-	-	86	23
1931–1970	1,2	613	34	5	46	3	80	25
1981–2010	0,9	532	53	9,6	36	3,2	89	25,8
1990–2019	1,0	570	58	16	47	3	105	35,5

Annex 3.

Table 8. Shapiro–Wilk test for Pleven station on a statistical sample of precipitation for the period 1980 –2019; w.p 0,05: critical test value at significance level $\alpha=0,05$

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
w	0,84	0,89	0,87	0,94	0,96	0,93	0,92	0,81	0,82	0,90	0,93	0,94	0,92
w.p 0,05	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94

Acknowledgements: This publication was prepared under INVEST FOR EXCELLENCE IN REGIONAL SUSTAINABILITY (INVEST4EXCELLENCE) project. The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101035815. Responsibility for the information and views set out in this paper lies entirely with the authors.