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Research article

Changes in Agro-climatic Indicators in the Korça Region

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Abstract

The productivity of agricultural crops depends on an optimal degree of genetic factors, climate, soil and level of agrotechnology. Climate changes have a significant negative impact on the productivity of agricultural crops. The study is focused on a multi-year analysis of the main climate indicators, such as temperature and precipitation. The data collected from hydrometeorological stations in the Korça region of Albania were processed and compared with the corresponding data from two previous 30-year periods. The increase in temperature indicated a trend without significant volatility from one year to the next, and the annual amount of precipitation did not fundamentally change; however, a greater concern was the amount of rain that fell over fewer days but in larger amounts. Moreover, the structure of the diagram which integrated temperature and average monthly rainfall showed that there had been an increase in the periods of drought. The changes in agro-climatic indicators present a challenge for producers in the field of agriculture if they are to meaningfully remodel agricultural areas and determine the most appropriate cultivation technologies for agricultural crops.

Keywords

bioclimatic indicators;

climate changes;

ecosystems;

precipitation;

region of Korça;

temperature

1. Introduction

Climate change affects the sustainability of crop production. The producers of agricultural crops are burdened with difficulties due to increase in temperature and fluctuations in the distribution of rainfall. In their scientific work, researchers from other countries argued that climate indicators are constantly changing. However, these data cannot be used for other agro-climatic zones. Climatic factors affect the development of plants in an integrated way and not in a separate way. Thus, the focus in this research was not only on the separate processing of the climatic indicators of temperature and precipitation, but also on the integration of those indicators.

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A study conducted by Peçuli and Kopali [1, 2] shows that the yield of agricultural crops varies from year to year even though cultivation techniques remain the same. Consequently, this variability derives from the direct or indirect influence of climatic factors and their interactions, which do not depend on humans. Climate change affects the entire cycle of plant development [3]. According to various studies conducted by the IPCC in Southern Europe, where Albania is located, it is forecasted that the occurrence of climate change will induce increases of temperature and decreased rainfall [4]. Temperature increase as a part of climate change has significantly affected the productivity of crops that are cultivated in the spring, such as beans, potatoes, sugar beets, and so on, as well as those planted in the fall, such as barley and wheat.

An important indicator of climate change that has been observed in this area is a decline in the number of snowy days, as well as a latening of the onset of snowfall. According to data published by the Hydrometeorological Institute in 1975 (these data reflect a summary of 30 years referring to the time periods 1931-1960 and 1961-1990) [5], the average number of days with snow on the Korça plain was 34.8, while the average start date of snow was December 11th. Data from the year 1990, obtained from the Hydrometeorological Institute and the Institute of Geosciences, Energy, Water and Environment, showed significant changes in these indicators. Over the last decade, the average number of snowy days on the Korça plain was 24.6, while the average start date of snow was January 3rd. Snow has an important role because it serves as a cover that reduces the impact of negative temperatures. This is a period when plants are in the fraternization phase. The reduction of the height of the snow is mainly determined by the location. The temperature-precipitation combination explains the changes in soil temperatures [6]. One of the most obvious effects of warmer winters is the reduction of the duration and thickness of the snow cover [7].

The changes in snow cover as a result of warmer winters bring in an annual change in soil temperature of 2-7°C [8]. Goodrich's study concluded that changes in snow cover could change the average annual temperature of the earth by up to 6°C [9]. The studies carried out by Ling and Zhang [10] showed that the date of the beginning of the snow cover in autumn and the date of its melting has an impact on the progress of plant development. The Mediterranean region (of which Albania is a part) has been defined as one of the regions which will be impacted by significant climate change [11, 12]. Cultivar selection is one of the best ways to cope with the negative effects of climate change and environmental stresses [13, 14]. It is predicted that with climate change, there will be significant increases in the maximum and minimum temperatures in all seasons [15]. The best way to deal with crop responses to a warmer climate is to assess the response of cropping systems. Crop phenology is one of the basic characteristics and serves as an indicator of production. It changes as crops adapt to changing environmental conditions [16-19]. The objective of the study was to assess the changes in climatic indicators for the region of Korce in Albania, based on scientific parameters. Furthermore, the study aimed to provide producers of agricultural crops with clear indications and conclusions about climate change.

2. Materials and Methods

2.1 Material

In this study, climatic data sourced, from meteorological stations located in the plain areas of Korça and Bilisht in Albania, were used. The data was related to meteorological indicators including temperature, precipitation, relative humidity, wind speed and direction, and solar radiation. Korça lies at an altitude of 850 m above sea level and has a Mediterranean mountainous and partly continental climate, with cold winters, and hot and dry summers. The average annual temperature reaches up to 10.6ºC. January is the coldest month, while August is the hottest. November is the wettest month, with an average rainfall of 104 mm, while the average annual rainfall reaches 720 mm.

2.2 Methods

The data was obtained from different sources, such as:

- The Hydro meteorological Institute-Academy of Sciences. Climate of Albania, Volumes I and II (data for the corresponding years 1931-1960 and 1961-1990)
- The Institute of Geosciences (data for the corresponding years 1991-2001)
- Monthly climate bulletins, Institute of Geosciences publications [20] (data for the corresponding years 2018 - 2021)

The data obtained for the studied time periods were processed, and different values of climate variables were noted, including:

- Records of average, maximum and minimum monthly and annual temperatures;
- Records of monthly and annual rainfall;
- Daily and monthly records of average, maximum and absolute minimum temperatures;
- Monthly recorded values of the number of days with relative humidity equal to or lower than 50 %;
- Monthly data of the number of days with relative humidity greater than or equal to 80% (≥ 80 %) for 14 h.

From a general ecological standpoint, the classification of climate is done based on the basis of climatic indicators. Generally, these indicators are focused on the thermal and precipitation regimes as the most important climate elements [21].

The determination of drought periods was calculated according to the Bagnlous and Gossen ombrothermic diagram method [22]. The temperature and precipitation trends and their tendencies were analyzed using regression equations and correlation coefficients, including the Emberger pluviometric indicator. The formula applied was:

$$Q = (M + m) \times (M - m) / 100\ R$$

where:

R - annual precipitation in mm; M - average of maximum temperatures of the hottest month (°C);

m - average of the minimum temperatures of the coldest month

Rivas - Martines Indicator [23]:

Temperature amplitude Ic = Tmax - Tmin;

Thermal index TI = (T + m + M) x 10 where:

Tmax average of maximum temperatures of the hottest month of the year (°C);

Tmin - average of minimum temperatures of the coldest month of the year (°C);

M - Average temperatures of the hottest month (°C);

m - average temperatures of the coldest month (°C);

T - average the sum of annual temperatures (°C).

3. Results and Discussion

From the processed data, the climatic features of the Korça plain and Bilisht were determined, based on the four analyzed variables: average rainfall (mm); average annual temperature (ºC); average number of days with relative humidity≥80 % annually, and average number of days with relative humidity≤50 % per 14 h. The obtained results were processed and compared with the data from a study conducted in 2013 in order to compare the pace with which these changes have occurred in recent years [24]. Tables 1 and 2 presents the records for climate indicators for the time period 2018-2021 in the region of Korça.

From the records presented in Table 3, it was observed that compared to multi-years data, the highest amount of precipitation (910 mm) recorded in 2018, and minimum (632 mm) recorded on 2020, were closer to the probability of coincidence with 75%. After processing the average, maximum and minimum monthly and annual temperatures, the differences between them were analyzed, as shown in Table 4 and Figures 1-3.

Table 1. Atmospheric temperatures during 2018-2021 [Meteorological Bulletins, published by the Institute of Geosciences, Energy, Water and Environment, related to the minimum and maximum temperatures for the years 2018-2021 in the Korça region]

Month	**Minimum average atmospheric temperatures (°C)**				**Maximum average atmospheric temperatures (°C)**			
	2018	**2019**	**2020**	**2021**	**2018**	**2019**	**2020**	**2021**
January	-1	-6.5	-3.4	-2.3	6.6	2.1	7	6.7
February	0	-2	-1	-1.7	6	8.4	10.2	10.1
March	2.2	1.8	1.9	0.3	12	15.2	12.1	9.1
April	4	4.8	3.6	3.7	21	16.4	16	15.1
May	11.6	8.2	8	9.1	22.6	18.2	22	21.5
June	12.6	13.9	12.6	12.8	24.4	27.1	24	26
July	15.3	14.9	15.1	15.2	27.5	28.1	29.1	28.1
August	14.8	15.6	15.4	15.4	26.2	30	27	27.5
September	11.4	12.2	11.8	11.5	24.8	25.2	25	24.9
October	9.9	8.6	6	8.1	18.7	21.4	19	19.8
November	4.1	5.8	1	3.5	12.3	13.8	13.4	13.3
December	-2	0.2	0.8	-0.2	6.4	8.2	9.4	8.1
Average	6.9	6.5	6	6.3	17.4	17.8	17.8	17.5

By comparing these data with the multi-year ones, we reached conclusions regarding the indicators of climate change.

Table 2. Average atmospheric temperatures (°C) in the Korça region [Processed by the Meteorological Bulletins published by the Institute of Geosciences, Energy, Water and Environment, related to the average temperatures for the years 2018-2021 in the Korça region]

Month	Average atmospheric temperatures (°C)			
	2018	2019	2020	2021
January	2.8	-2.2	1.8	2.2
February	3	3.2	4.6	4.2
March	7.1	7.5	7	4.7
April	12.5	10.6	9.8	9.4
May	17.1	13.2	15	15.8
June	18.5	20.5	18.3	19.4
July	21.4	21.5	22.1	21.4
August	20.5	22.8	21.2	21.5
September	18.1	18.7	18.4	18.3
October	14.3	15	12.5	13.7
November	8.2	9.8	7.2	8.4
December	2.2	4.4	5.6	3.9
Average	12.1	12	11.9	11.9

The average temperature of the atmosphere (°C) was calculated based on the basis of data processing, according to the methodology.

Table 3. Average precipitation for the corresponding years in the Korça region [Meteorological Bulletins published by the Institute of Geosciences, Energy, Water and Environment, related to monthly and annual amount of rainfall for the years 2018-2021, in the Korça region]

Month	Precipitation (mm)						
	2018	2019	2020	2021	Average 2018-2021	Average 1961-1990	Average 1931-1960
January	52	145	15	172	96	47	70
February	47	12	45	87	48	54	68
March	123	12	115	52	76	46	53
April	12	55	54	53	43	48	54
May	128	82	41	18	67	62	58
June	145	65	41	85	84	45	42
July	25	74	38	32	42	32	21
August	160	21	112	22	79	23	25
September	8	17	32	35	23	38	44
October	12	25	56	67	38	76	85
November	156	184	12	52	101	105	112
December	42	74	71	65	63	75	89
Total	910	766	632	740	760	651	721

The data shows that the climate is becoming drier and warmer.

Table 4. Records of monthly and annual temperatures for the corresponding years

Months	Minimum average atmospheric temperatures (°C)		Maximum average atmospheric temperatures (°C)		Average atmospheric temperatures (°C)		
	2018-2021	1961-90	2018-2021	1960-90	2018-2021	1931-1960	1961-1990
January	-3.3	-3.8	5.6	3.8	1.1	0.5	0
February	-1.2	-2.2	8.7	5.4	3.8	1.8	1.6
March	1.6	- 0.2	12.1	9.8	6.6	4.9	4.8
April	4	4.4	17.1	14.4	10.6	9.7	9.4
May	9.2	8.1	21	19.7	15.3	14	14.5
June	13	11.4	25.4	23.6	19.2	17.8	17.5
July	15.1	12.8	28.2	26.2	21.6	20.5	19.5
August	15.3	12.6	27.7	25.6	21.5	20.8	19.1
September	11.8	9.8	25	22.6	18.4	17.3	16.2
October	8.2	5.5	19.7	17.1	13.9	11.5	11.3
November	3.6	1.9	13.2	10.7	8.4	7.2	6.3
December	-0.3	-2	8	5.8	4	2.8	1.9
Average	6.5	4.9	17.5	15.4	12	10.7	10.2

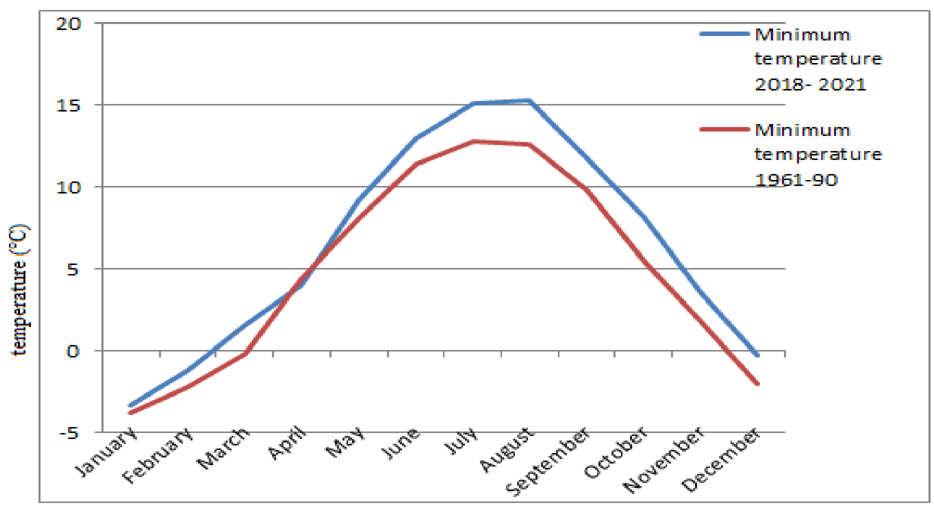

Figure 1. Graph of minimum atmospheric temperature (°C) by month over the periods 1961-1990 and 2018-2021

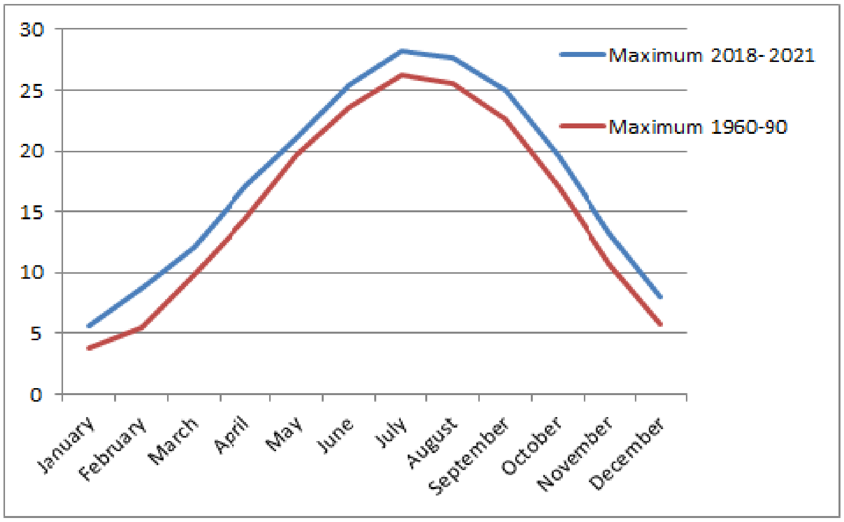

Figure 2. Graph of maximum atmospheric temperatures (°C) by months for the periods 196-1990 and 2018-2021

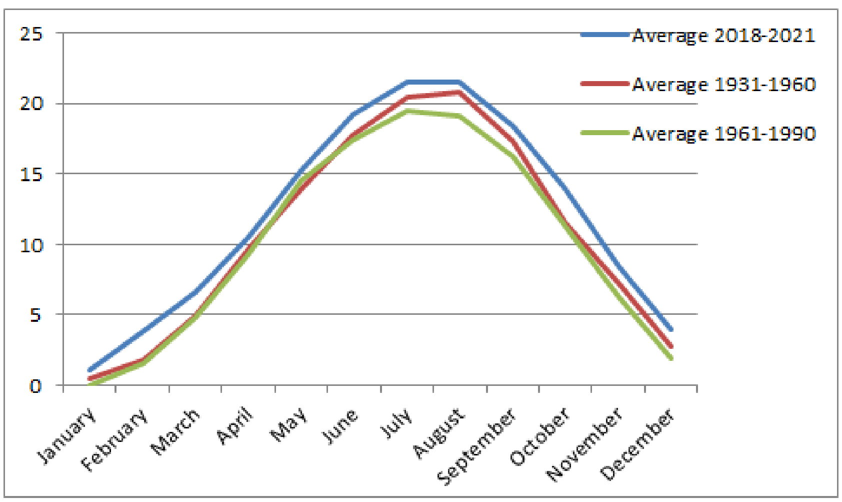

Figure 3. Graph of average atmospheric temperatures (°C) by months for the periods 1931-1960, 1961-1990 and 2018-2021

From the data presented, an increase in the average air temperatures was observed. For the corresponding period 2018-2021, the average minimum atmospheric temperatures had increased by 1.6°C, the average maximum temperature had increased by 2.1°C, while the average temperature showed an increase by 1.8°C.

The highest increase in temperatures occurred over the periods of February-March and June-August. Based on the data analysis, it can be argued that the significant increase of temperatures directly affected the performance of plant cultivation. The increase in temperature was determined by other studies [2], but the growth rates were higher. Temperature is one of the most important ecological elements. It determines the intensity of various plant functions such as germination, photosynthesis, respiration, and accumulation of organic matter. We emphasized that barley crops were sensitive to biological minimums which presented significant challenges for cultivation after autumn. By integrating the data records on temperatures and precipitation via the Bagnoulus-Gaussen ombrothermic diagrams, the timing of the drought periods in Korça region were determined (Figure 4).

Based on the data shown in Figures 4 and 5, it was concluded that climate change had significantly influenced drought periods. From the graphic analysis of agro-climatic context, it was observed that drought over the period 1961-1990 in the region of Korça started from the first 10

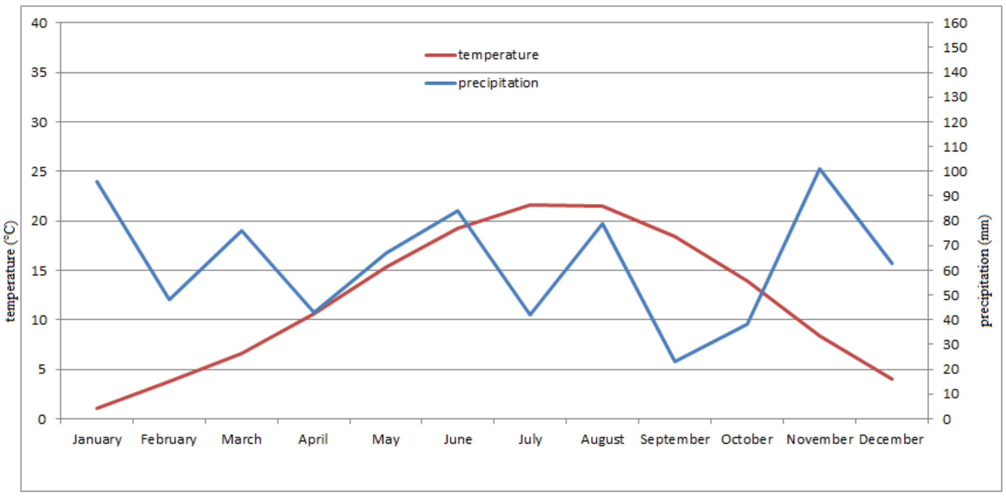

Figure 4. Bagnoulus and Gaussen ombrothermic diagram for drought periods in Korça region (2018-2021)

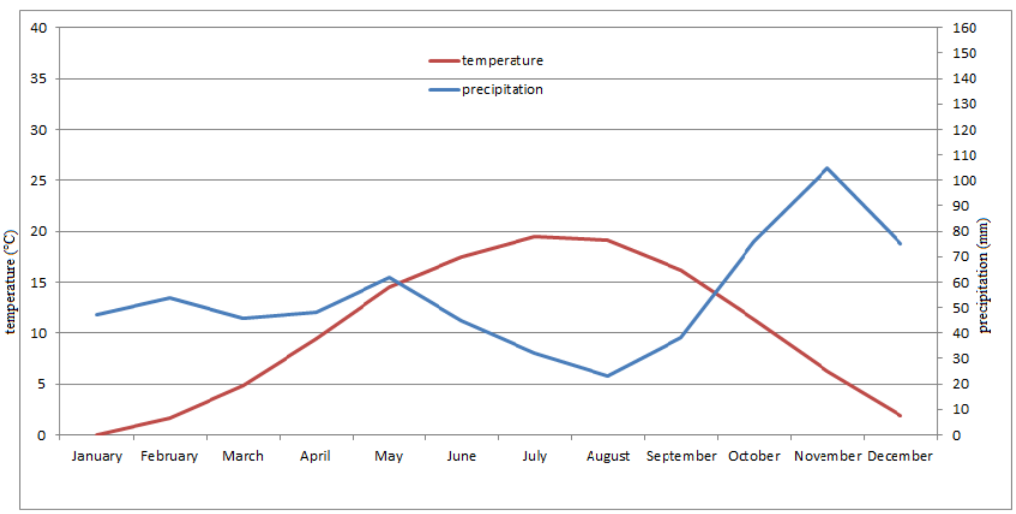

Figure 5. Bagnoulus and Gaussen ombrothermic diagram for drought periods in Korça region (1961-1990)

days of June and continued until the 20th of September (Figure 2). On the other hand, for the period 2018-2021, drought starts from the first 10 days of June and continued until the 20th of October (Figure 1). Based on that, it was easily identified that there was a one month extension of the drought period. There were also significant changes in monthly precipitation for this period. From the data observed, it indicated a trend of increased temperatures throughout the year; however, it was difficult to conclude the same for the amount of precipitation. From the study of these diagrams, we came to the conclusion that climatic factors affected the development of plants not separately but in fact in an integrated way.

4. Conclusions

From the analyzed data in terms of climate and its comparison with the two 30-year range periods of 1931-1960 and 1961-1990, it could be concluded that during the period 2018-2021, the average atmospheric temperature increased by 1.8°C. The maximum atmospheric temperature increased by 2.1°C. The highest increase in temperatures occurred in the periods from February to March and from June to August. In the agro-climatic context, for the period 2018-2021, drought started in the first 10 days of June and continuing until the 20th of October. Based on that, it was concluded that there was a one month extension of the drought period. For the same period, significant changes in the monthly precipitation also occurred. A trend of increased temperature throughout the year was also note, while it was difficult to conclude the same for the amount of precipitation. Over the last decade, the average number of days with snow on Korça plain has decreased by about 10 days. The average start date of snow has been postponed for about a month.

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