Effect of climate change trends on viticulture in the region

M.Yu. Gerasimova, *Yu.V.* Pismenskaya* and *M.A.* Modina

Admiral Ushakov Maritime State University, 93 Lenin Ave., Novorossiysk, 353924, Russian Federation

Abstract. The paper addresses the assessment of changed agroclimatic indicators in the conditions of the Krasnodar Territory and the analysis of their effect on the yield of grapes in the region. The effects of climate change can be both negative (increased frequency and intensity of dangerous hydrometeorological phenomena; increased range of insect pests, etc.) and positive (long-term growing season and heat supply for agricultural crops, etc.). Thus, reliable and timely data on the climate state and change are needed for a comprehensive understanding of the problem. The results of data analysis and conclusions about the climate state and change in the Krasnodar Territory, in particular the city of Novorossiysk, form the data basis for development of adaptation measures and play an important role in studies into climate variability and anthropogenic climate change.

1 Introduction

Climate change remains one of the most important challenges and threats to humanity. Agriculture is the most climate-dependent sector of the economy. The results of many studies show the effect of climate change on agriculture in general and viticulture in particular. The effect of climate change is manifested at the regional level, which requires viticulture adaptation.

According to the OIV (International Organization for Viticulture and Winemaking), in 2020 Russia ranked 20th in terms of vineyard area, 12th in terms of wine production and 6th among the largest importers of wine [1, 2].

There are seven wine regions in Russia: the Terek Valley in Kabardino-Balkaria, Kuban, Dagestan, North Ossetia-Alania, the Don Valley in Rostov Region, and Stavropol.

Kuban (Krasnodar Territory) includes nine wine regions (Taman Peninsula, Gelendzhik, Abinsk, Novorossiysk, Anapa, Afips River Valley, Eastern Azov Region, Krymsk, Novokubansk).

Viticulture and winemaking are priority sectors in the economy of the Krasnodar Territory, where vineyards occupy 28,300 hectares, which is 32% of the total vineyard area in Russia [7]. The contribution of the region to the country's total volume of harvested grapes is approaching 40%. The gross harvest in 2021 amounted to 180 thousand tons of grapes.

The main vineyards areas of the Krasnodar Territory are located in:

- Temryuk district, 19.0 thousand ha;
- Anapa, 4.0 thousand ha;
- Novorossiysk, 1.7 thousand ha;
- Krymsky district, 1.3 thousand ha;
- Gelendzhik, 0.3 thousand ha [4].

2 Materials and methods

Meteorological data on the temperature regime and moisture availability in 2006–2021, yield and gross grape harvest indicators in 2010–2021, and frequency of dangerous meteorological phenomena in 1997–2021 were analyzed to determine the local climate change trends and their effect on agroclimatic conditions in the viticulture zone of the Krasnodar Territory.

3 Results and discussion

Table 1summarizes the main indicators of viticulture development in the Krasnodar Territory in 2010–2021 [3, 4].

Table 1. Indicators of the viticulture development in the region

Indicator	Year							
	2010	2015	2016	2017	2018	2019	2020	2021
Vineyard area, thousand ha	24.6	25.9	25.4	25.0	26.6	27.0	27.5	28.3
Gross harvest, thousand tons	135	183	240	202	218	212	193.5	180
Yield, q/ha	79.0	84.6	114.8	93.0	99.3	100	95	90

Gross harvest in 2021 decreased by 7% compared to that in 2020 and by 25% compared to that in 2016. The trend of sustainable growth of vineyard areas can be observed in the Krasnodar Territory.

* Corresponding author: yuliyapismenskaya@mail.ru

Figure 1 shows the dynamics of the gross grape harvest in the Krasnodar Territory.

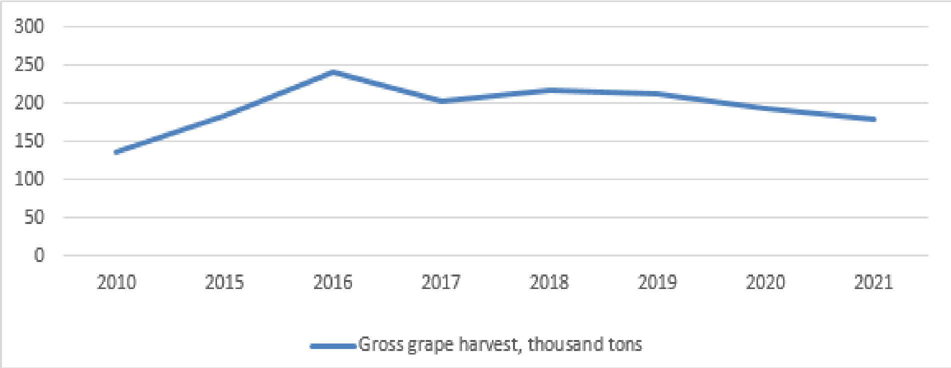

Fig. 1. Gross grape harvest in the Krasnodar Territory

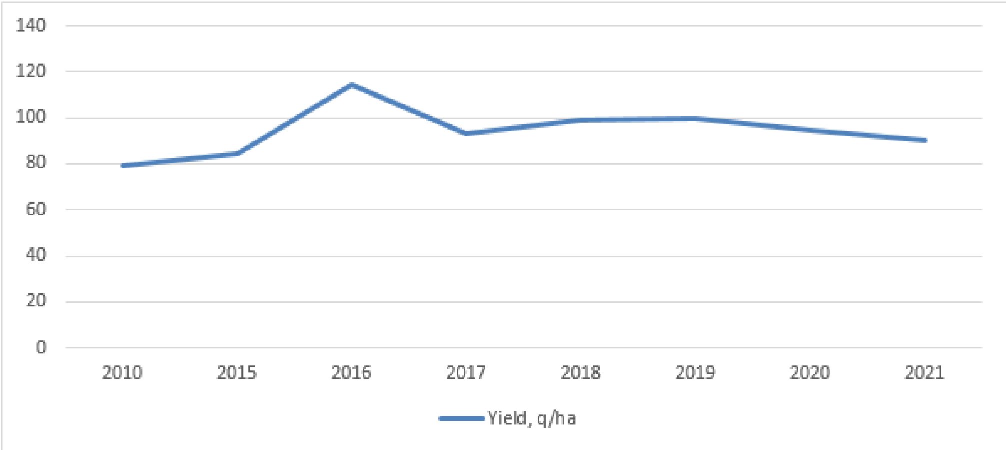

Fig. 2. Grape yield in the Krasnodar Territory

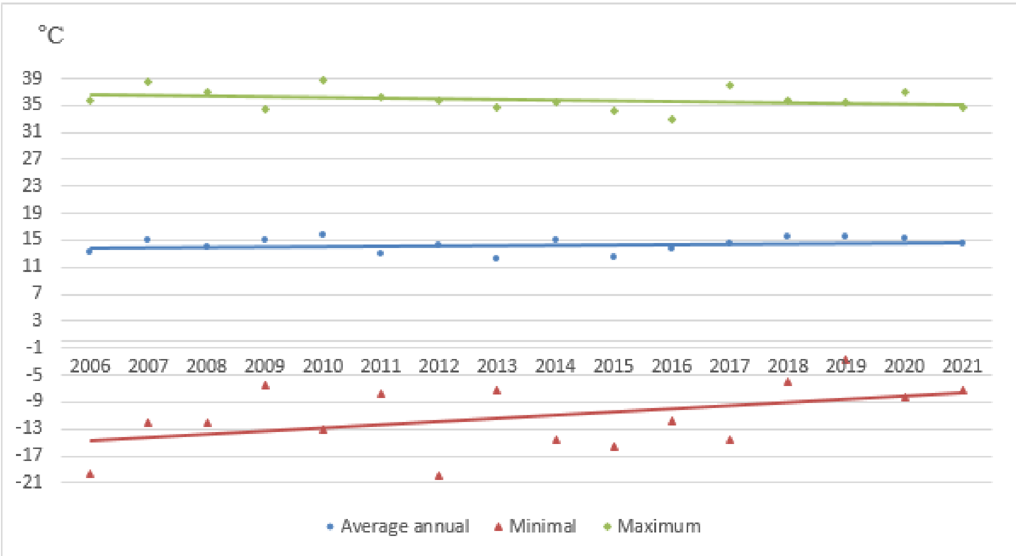

Fig. 3. Temperature regime according to the meteorological station in Novorossiysk.

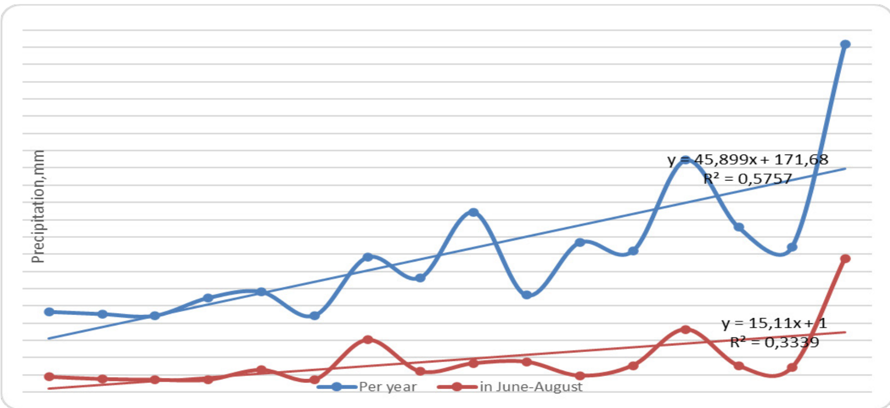

Fig. 4. Change in the annual amount of precipitation and the amount of precipitation in the warm period.

Figure 1 shows a constant fluctuation of the gross harvest in 2010–2018. Since 2019, this indicator has declined, which is due to the fact that the volumes of the gross grape harvest primarily depends on the frequency and intensity of dangerous meteorological phenomena that cause losses to vineyards and the climatic conditions in the region.

Figure 2 presents the dynamics of grape yield in the Krasnodar Territory [3, 4].

Figure 2 shows that the highest grape yield was observed in 2016 (114.6 q/ha). In 2021, the yield of grapes decreased by 24.8 q/ha compared to that in 2016 and by 7% compared to that in 2020.

Novorossiysk is a city of Kuban, where viticulture is one of the promising sectors of the agro-industrial complex. In 2019, the vineyard area amounted to 1,716 hectares (1,300 hectares in 2017). In 2020, 85 hectares of new vineyards were planted on the territory of Novorossiysk. The gross grape harvest in 2019 amounted to 12.5 thousand tons (10.5 thousand tons in 2018). On the territory of Novorossiysk, 15 limited liability companies (OOO) and 14 peasant farms are engaged in viticulture and winemaking. The total area occupied by vineyards in Novorossiysk in 2021 amounted to 1,842 hectares. The largest wine producers in Novorossiysk include the following wineries: Abrau-Dyurso, Myskhako, Tristory, Fervino, Sort, Sikora's estate, Chateau Pino.

According to 15-year data provided by Novorossiysk weather station, the average daily air temperature is 14.5 °C, the average daily temperature during the forced dormancy of the vine (January–February) is 4.7 °C, and the average temperature during the active growing season (May–September) is 22.9 °C. The maximum temperature during the growing season attained +38.7 °C (08.08.2010), and the minimum temperature during the wintering period dropped to –19.8 °C (February 8, 2012) [5].

The climate in Novorossiysk region is subtropical dry, close to mediterranean. In winter, air masses of temperate latitudes dominate in the region, while in summer they are tropical. The climate of Novorossiysk is characterized by a heavy northeasterly wind called nord-ost or bora and floods. Nord-Ost occurs when cold air invades the Black Sea coast from the North Caucasian plateau. At the same time, cold air flowing over the mountains look like a giant descending 'beard'. When nord-ost occurs, air temperature drops sharply (temperature can drop by 10–15 degrees within one hour). The wind speed reaches 30–70 m/s, which is extremely dangerous for ships [9, 10, 12–14].

Trends in air temperature changes provided by the Novorossiysk meteorological station are shown in Fig. 3.

The growth rate of the Novorossiysk-averaged annual temperature (linear trend) was + 0.74 °C/ 15 years. The recurrence of stress negative temperatures in winter decreased.

Figure 4 shows the dynamics of indicators of the humidification regime in Novorossiysk.

Analysis of the data on the amount of precipitation provided by the Novorossiysk meteorological station revealed an upward trend in the annual amount of precipitation and in the amount of precipitation over the period of growth and ripening of berries (June–August).

One of the adverse effects of climate change is the increased frequency and intensity of dangerous meteorological phenomena that cause huge losses to the farms of the Krasnodar Territory [11, 15].

Figure 5 shows the types and number of phenomena that caused economic damage in the municipalities of the Krasnodar Territory in 1997–2021 [6].

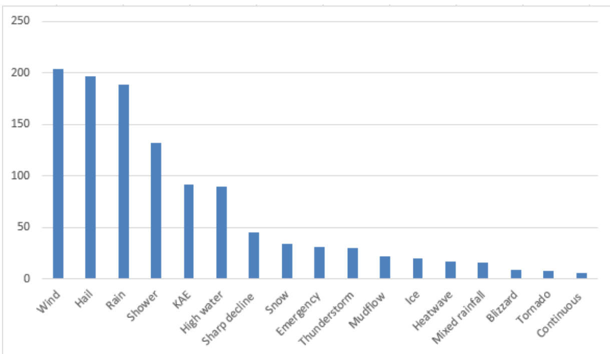

Fig. 5. Types and number of hazardous phenomena and adverse hydrometeorological phenomena that caused damage on the territory of the Krasnodar Territory in 1997–2021 (KAE is a complex of adverse events).

In the region, the damage is typically caused by strong winds, hail, and intense and continuous rains [16].

In the Krasnodar Territory, phenomena dangerous for agricultural production in the warm season include frosts, atmospheric drought, soil drought, dry winds, strong winds, and hail. The adverse weather conditions are among the phenomena dangerous for agricultural production in the cold season, which cause damage and death of agricultural crops: winterkill, ice covering, low air and soil temperatures that cause damage to the root system of grape vines [8].

A total of 184 types of hazardous events (HE) were observed on the territory of Novorossiysk in 1997–2021. Of these, 57 were heavy fogs, 52 – heavy rain, 41 – strong wind, 16 – heavy shower, and 15 – heavy snow [6].

For example, summer flooding in 2021 decreased the yield of grapes. In June–August 2021, a 5-fold increase in the amount of precipitation was observed in the region. The mesocyclone passed through the Krasnodar Territory in August. Flooding led to the loss of 13.5 thousand tons of grapes and the average yield was 90 q/ha.

The intense sun and dry summer improve the wine quality. Good quality grapes absorb sugar needed for making wine. If the grapes are subject to high humidity with heavy rains, they absorb a lot of moisture and the accumulated sugar and various microelements are washed away. This reduces the quality of grapes since they become watery[17–21].

At the same time, a significant increase in air temperature during active vegetation had a positive effect on the accumulation of sugar in grapes. However, earlier spring processes and decreased air temperature in April led to a damage of vineyards by late spring frosts. In recent years, there has been an increase in the number of fungal diseases due to climate change that creates favorable conditions for plant diseases.

Two types of response to climate change are widely recognized: limitation and adaptation. Limitation aims to prevent and slow down the growth of greenhouse gas concentrations in the atmosphere. Adaptation requires consideration of both adverse and positive effects of climate change. An important link in adaptation is the solution of the agrometeorological problem, which implies the assessment of changes in the agroclimatic conditions for cultivation of agricultural crops and the effect of these changes on their productivity [22–24].

Analysis of data on the yield and weather and climatic conditions revealed the main factors that cause economic damage to viticulture reducing the yield and quality of grapes: 1) adverse weather conditions in spring during the inflorescence differentiation; 2) dry phenomena; 3) strong wind; 4) heavy precipitation and low air temperatures during the ripening period; 5) adverse weather conditions during flowering (temperature drops below 15°C, high humidity, precipitation); 6) damage caused by low temperatures in winter; 7) damage caused by spring frosts; 8) hail; 9) fungal diseases (intensive development of diseases in optimal weather conditions: high humidity and temperature 20–25°C).

4 Conclusion

The study revealed climate change trends, which affect viticulture in the region. It was shown that an increase in the average annual temperature, in the amount of precipitations during the growth and ripening of grapes, and in the frequency and intensity of hazardous events cause huge losses to the wine industry.

Thus, warming in the Krasnodar Territory in the near future will have both positive and negative effects on the productivity of grapes.

Possible positive effects include: 1) increase in the growing season duration; 2) absence of early autumn frosts; 3) increase in the amount of precipitations in January–March and cool weather in April are favorable for the formation of a larger number of inflorescences; 4) earlier technical ripening; 5) increase in sugar concentration.

Possible adverse effects include: 1) late spring frosts; 2) increase in the number of dangerous meteorological phenomena; 3) successful overwintering of pests and weeds; 4) unsuitability of some grape varieties for the production of wine of a certain type and traditional quality; 5) increase in vegetative activity and productivity of grapes to the detriment of the yield quality.

Adaptation measures due to global warming include: 1) new agro-climatic zoning; 2) selection of new varieties resistant to unstable weather conditions; 3) optimization of the placement of vineyards in rugged terrain; 4) use of new preparations to protect vineyards from pests, diseases and weeds 5) development of new agricultural methods to improve the retention of moisture in the soil.

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