Coğrafiya elmləri / Geographical Sciences

IMPACT OF DECREASING PRECIPITATION ON SOIL MOISTURE LEVELS IN THE ABSHERON PENINSULA

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Abstract. This article examines the dynamics of precipitation throughout the Absheron peninsula and its impact on lands suitable for agriculture based on Landsat satellite data from 1975 to 2020. The analysis of corresponding linear trends for reviewed period revealed the statistically significant changes in precipitation across the peninsula. Thus since 2005, the significant decrease has been observed in annual precipitation which may be one of the reasons for the Caspian Sea level dropping in recent years. Reduced precipitation will disrupt the soil moisture balance, water reserves, and ultimately reduce agricultural productivity. In the article, we used the NDWI (Normalized Differential Water Index) coefficient to analyze the dynamics of precipitation decline and its impact on vegetation cover.

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Introduction

The level of the Caspian Sea has always been subject to changes. Like the rise in sea level its decrease also have had a number of negative effects.Such as, despite that 3820 ha land were submerged in 1977-1995, currently 2029 ha land have emerged and the length of the coastline is 289.6 km. Since 2005 the sea level has been continiously decreased at an average rate of approximately 10–15 cm per year (Aliyev, 2024).The areas which are most negatively affected by this reason are precisely the coastal zones. The negative impact of the sea level changes also manifested on the Absheron Peninsula which plays a crucial role in economy of our country (Mammadov, 2015). If the aforementioned process continues and sea level drops to −30.0 m, the probability of the following negative impacts occurring in our study area may increase:

- The area of water surface (100–50 km²) and volume (0.8–0.4 km³) of the Baku Bay may decrease by up to 2 times. (Compared to sea level in 1930). In this case the water exchange between the bay and the sea may decrease up to 3 times.

-The height of the wind waves decrease from 3 m to 0,8 m, and the height of high tidal waves decrease from 1 m to 0.5 m.

- Significant changes of the landscape (configuration) of the northeastern and eastern parts of the Absheron Peninsula;

-Significant shallowing of the Northern and Southern Absheron bays

-Chilov Island may merge with Pirallahi Island (formerly Artem)

-Peschany Island may become connected to Cape Sultan;

-Shah Cape can dry out completely;

Among the negative processes mentioned above, one of the most important is the decrease in precipitation (Mammadov, 2008; Safarov et al., 2023). A decrease in atmospheric precipitation negatively affects the development of the agriculture on peninsula, water supply for population, the reduction of existing flora and fauna, and the extinction of some of them, and other negative situations. The decrease in the amount of precipitation is negatively affecting soil moisture levels. The continuation of this trend is leading to the cultivation of drought-resistant dry subtropical plants in the study area. For this reason, the study of the level of moisture in the study area is extremely important.

Research method

The aim of this study is to monitor events occured over the period of 45-years, while at the same time, analyze them as thoroughly as

possible. Therefore, satellite images were selected accordingly.Landsat satellites, specifically Landsat 5, 7 and 8-9, were used to cover a period from 1993 to the present (Baishev et al., 2024; Mammadov & Gardashov, 2010). Some images from Landsat 5 and Landsat 7 were used. The result was an average of 36 images obtained for each area, but in the article we provided only Normalized Difference Water Index (NDWI) values for the years 1993 and 2000.

Analysis and Discussion

Climate is formed as a result of the influence of a number of main climate-forming factors, such as solar radiation (geographical latitude), atmospheric circulation (dominant air masses), and the characteristics of the surface cover (land or water surface etc.) (Ahadov et al., 2025). Among the factors mentioned in the formation of the climate of the Absheron Peninsula, also in addition to latitude, the Caucasus Mountains and the Caspian Sea play a significant role.

The Absheron Peninsula is distinguished from other regions of our republic by the fact that its north-south airflows are very strong. The main reason for the formation of these airflows is the high pressure area created by the Black, Scandinavian, and Azores High over Southeastern Europe (Madatzadeh, 1960). With the entry of these air masses into Absheron, the synoptic conditions deteriorate sharply, strong, stormy winds blow, the temperature drops, it snows, and in summer, southern, southwestern, and southeastern winds prevail.

Surrounded on three sides by the unfreezing, warm waters of the Caspian Sea and to the north by the Greater Caucasus Mountains, the climate of the Absheron Peninsula is characterized by being dry and hot. The number of sunshine hours here is greatest in the summer months. The duration of sunshine is 2244 hours per year, with a maximum of 319 hours in June and a minimum of 85 hours in December (Madatzadeh, 1960). The annual amount of solar radiation is 132.8 kcal/cm^2, with its amount in June being 19.2 kcal/cm2 and in December 3.7 kcal/cm^2. The annual amount of radiation balance is 59 kcal/cm2 (maximum in June 9.6 kcal/cm^2, minimum in December 0.7 kcal/cm^2).

The average annual temperature on the Absheron Peninsula is 14-15ºC. In January, this indicator is 3-4ºC, and in July it is 24-26ºC. In July, the temperature on the peninsula rises to 40-42ºC (Mammadov, 2008).

The annual amount of precipitation in the study area varies between 150-250 mm. The northern part of the peninsula receives more precipitation than the southern part. The maximum precipitation is observed in November (24-45 mm), the minimum in July (3-5 mm) (Mammadov et al., 2010). The duration of precipitation is an average of 86-96 hours per month for the cold period, and 3 hours per month in summer. Snow is not observed often and snow cover on the ground surface is almost non-existent. In rare cases, it is observed when the air temperature is low, which lasts approximately about 10-15 days.

The average annual amount for relative humidity is 70-73%, reaching 75-80% in January and 58-66% in July (Madatzadeh, 1960).

The characteristic wind for the Absheron Peninsula is the north wind called Khazri (or Baku Nord). Under the influence of north winds, the temperature drops, storms are often observed. The annual frequency of north winds is 60%, south winds - 19%, northeast winds - 17%. East winds are observed less often, which is about 2%. The average annual wind speed varies between 6-7m/sec (Madatzadeh, 1960). The highest average speed is observed in March (7.6-14.6m/sec).

In recent periods, a decrease in precipitation has been observed across the Absheron Peninsula. One of the reasons for this is that the evaporation coefficient has became less than one due to the drop in the level of the Caspian Sea.

To determine the dynamics of precipitation in the study area, the data of the Baku and Mashtaga stations located in the north and south of the peninsula were analysed. Thus, if we analyze the last 110 years of precipitation data of the Baku station, it was determined that the average annual minimum coincided with 1925, which was 78 mm (Mammadov, 2013). The average annual maximum (499 mm) for the Baku station was recorded in 2006.

Analysis of precipitation data for Mashtaga station. If we pay attention to the annual precipitation trend for Mashtaga station, we indicate a decrease in precipitation for the station. The maximum precipitation for the period 1975-2020 was recorded in 1980 and this indicator is equal to 186 mm (Huseynov, 2011). The minimum value for Mashtaga was observed in 2020 (Figure 1).

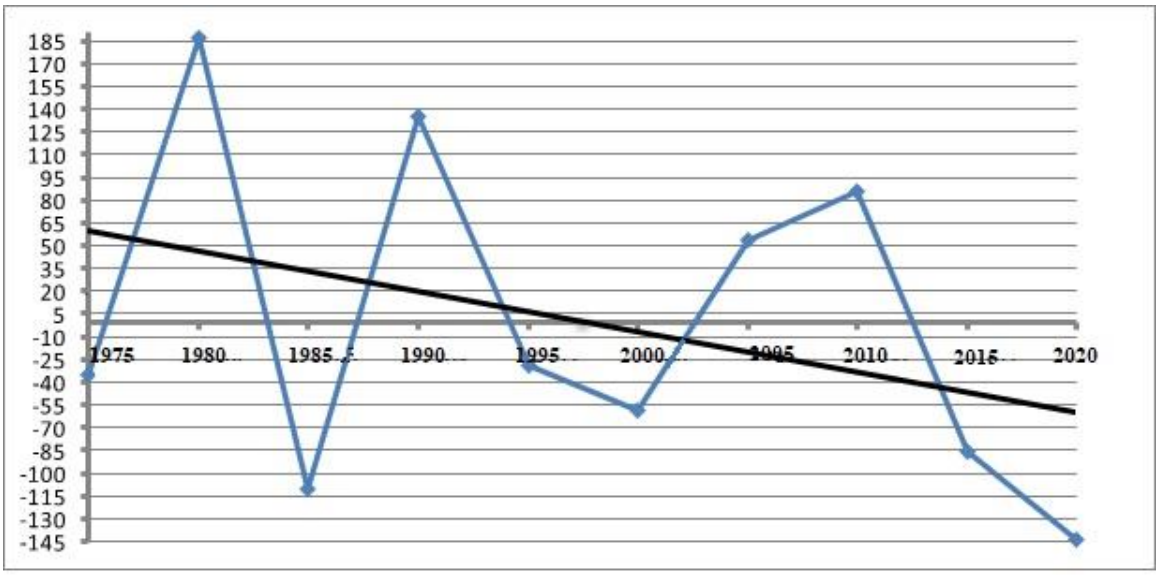


Fig. 1. Average annual precipitation in Mashtaga, in mm
(Huseynov, 2011; Mammadov & Gardashov, 2010)

If we pay attention to the trend for the spring season of the same station, we indicate that the precipitation regime has not changed much. For Mashtaga in 1975-2020, the spring maximum was recorded in 2010 and this indicator was 126 mm. The spring minimum was observed in 2015 (14 mm) (Figure 2).

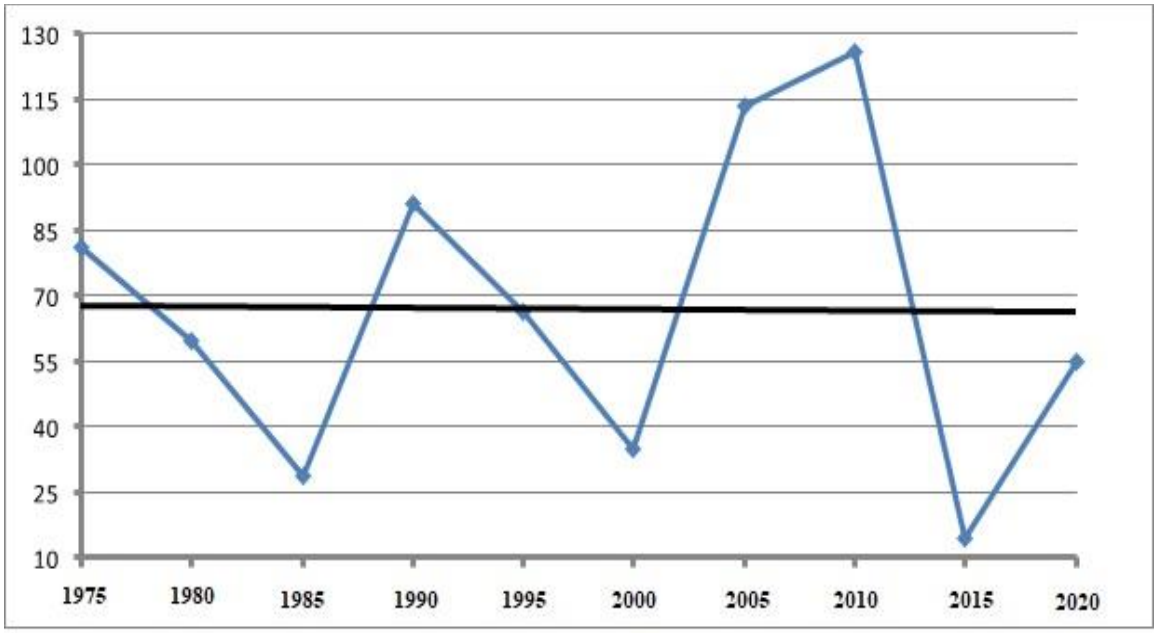


Fig. 2. The average precipitation for the spring season in Mashtaga, mm
(Huseynov, 2011; Mammadov & Gardashov, 2010)

If we pay attention to the trend we compiled based on the data of the Mashtaga station for the summer season of 1975-2020, we indicate the decrease in precipitation in those years. A decrease has been observed in the precipitation regime since 1980. In 2010, this indicator reaches its maximum value (58 mm). The minimum indicator for the summer season was observed in 2020 and is 0.5 mm. (Figure 3).

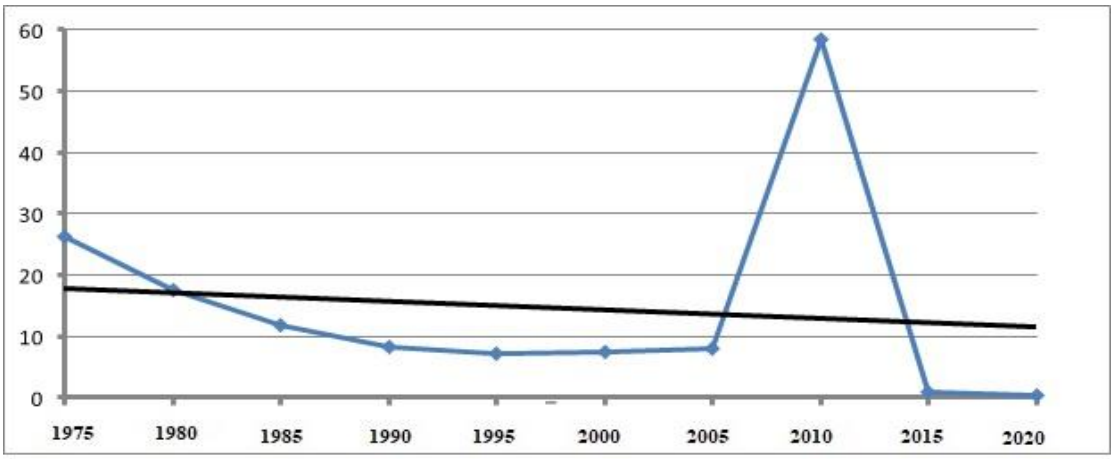


Fig. 3. Average annual precipitation for the summer season in Mashtaga, in mm
(Huseynov, 2011; Mammadov & Gardashov, 2010)

The 45 years of precipitation data which is compiled based for the Mashtaga station reveals a significant decrease in the precipitation regime. A considerable difference is observed between the maximum and minimum values. For the autumn season, the maximum indicator in those years was determined as 270 mm and was observed in 1980. The minimum indicator was observed in 2020 and is 20 mm (Figure 4).

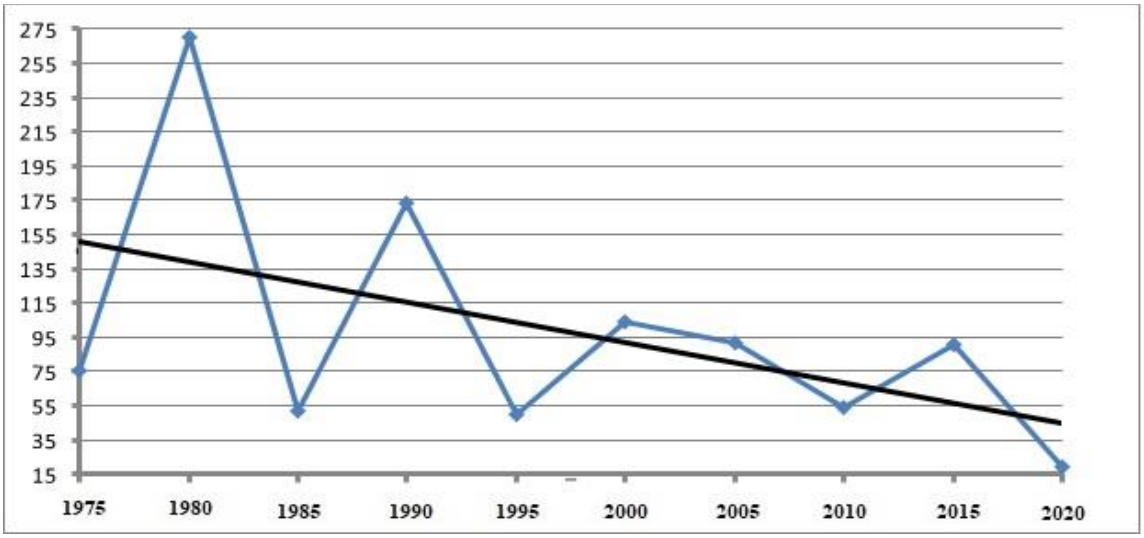


Fig. 4. Average annual precipitation for the autumn season in Mashtaga, in mm
(Huseynov, 2011; Mammadov & Gardashov, 2010)

The data compiled for the winter season shows a different pattern compared to the other seasons. If we pay attention to the trend, an increase in precipitation in the winter season was determined for the Mashtaga station in those years. The maximum value in those years occurs in 2010 and this indicator is 109 mm. The minimum value for the winter season was recorded in 1975 (13 mm) (Figure 5).

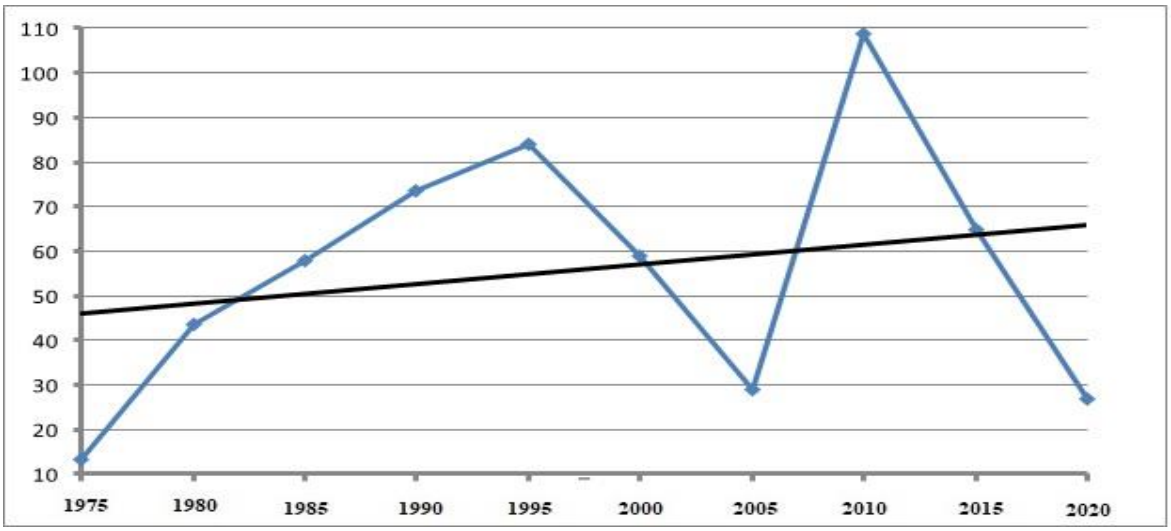


Fig. 5. Average annual precipitation for the winter season in Mashtaga, in mm
(Huseynov, 2011; Mammadov & Gardashov, 2010)

Analysis of Precipitation Data for the Baku Station. If we pay attention to the annual trend of changes in precipitation for the Baku station, we indicate the decrease in precipitation was recorded in those years. The highest precipitation for the Baku station was recorded in 2010 and this amount was 119 mm. The decrease in 1980 and 1990 was relatively small, and in other years it was high. The least precipitation was recorded for the Baku station in 2020. (Figure 6).

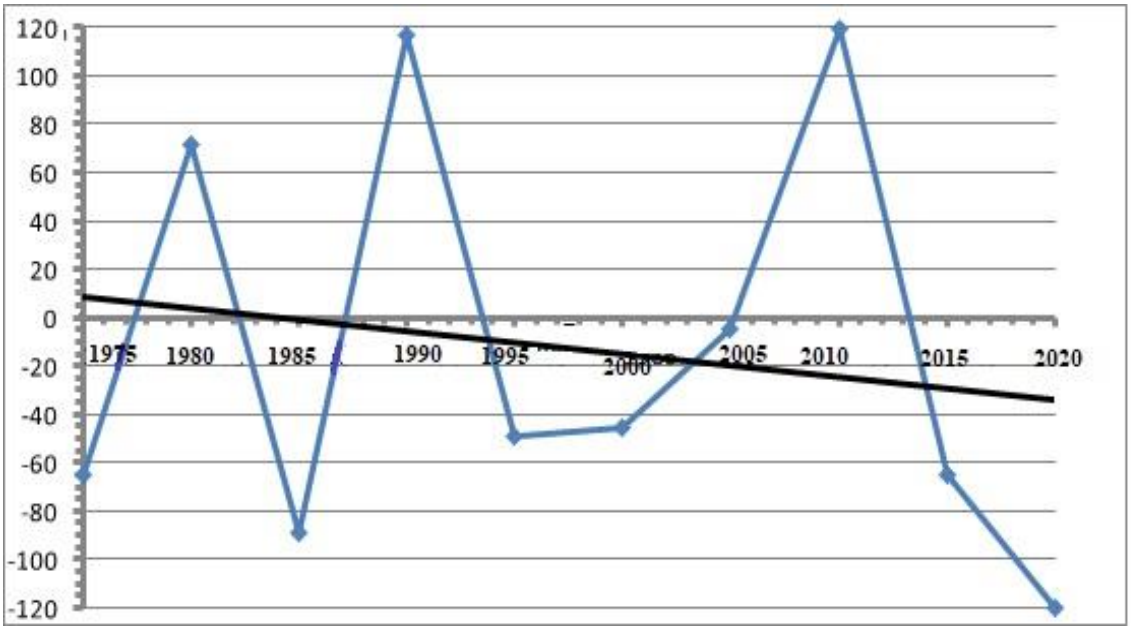


Fig. 6. Average annual precipitation in Baku, in mm
(Huseynov, 2011; Safarov, 2000)

If we pay attention to the trend of precipitation in the winter season at the Baku station, we indicate that precipitation decreased in the winter months in those years. The maximum precipitation was observed in the winter months for the Baku station in 1990 which was the 102 mm (Mahmudov, 2007). In subsequent years, precipitation intensity diminished considerably. The minimum indicator was recorded in those years in 2005 and this indicator for the Baku station is 17 mm (Figure 7).

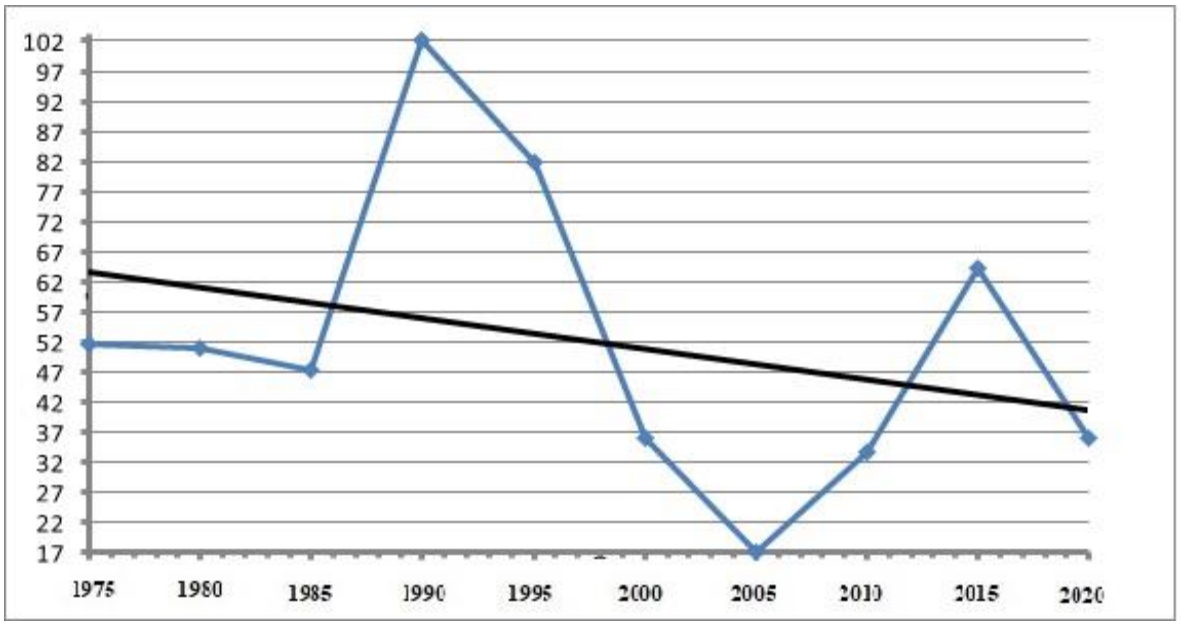


Fig. 7. Average annual precipitation for the winter season in Baku, in mm.
(Huseynov, 2011; Safarov, 2000)

If we pay attention to the analysis of spring precipitation data for the Baku station for 1975-2020, indicates a decrease in precipitation for those years again. The maximum indicator for the spring season during this period was recorded in 2010 and this indicator is 118 mm. The decrease in precipitation is less in 1975 and 1990 than in other years. The minimum amount for the spring season at the Baku station was observed in 2015 (12 mm) (Figure 8).

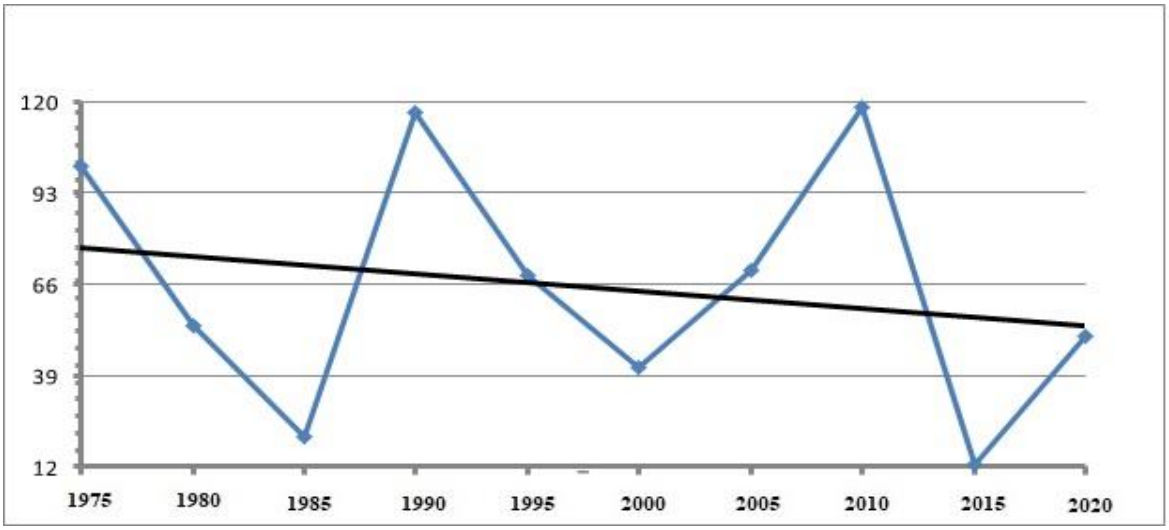


Fig. 8. Average annual precipitation for spring in Baku, in mm
(Huseynov, 2011; Safarov, 2000)

The trend of precipitation for the summer season shows a decrease in precipitation for the Baku station from 1975 to 2020 (Mahmudov, 2007). Similar to spring, the maximum summer precipitation was recorded in 2010, which was 94 mm. The minimum value was observed in 2020, at 0.5 mm, and which differing by 0.1 mm than the value recorded in 2015 (Figure 9).

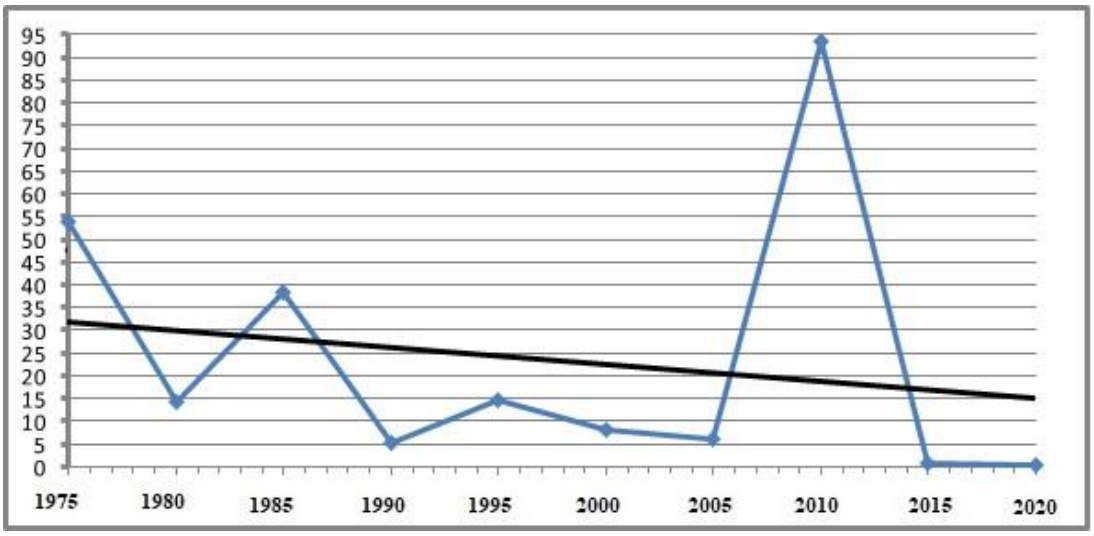


Fig. 9. Average annual precipitation for the summer season in Baku, in mm
(Huseynov, 2011; Safarov, 2000)

The trend of precipitation for the autumn season at the Baku station indicates the decrease in precipitation over the 10 years. The maximum indicator for the autumn season in those years is 164 mm, which was recorded in 1980. During the other years, less precipitation were observed. The minimum indicator for the autumn season for the Baku station was recorded in 2020 and which was 18 mm (Figure 10).

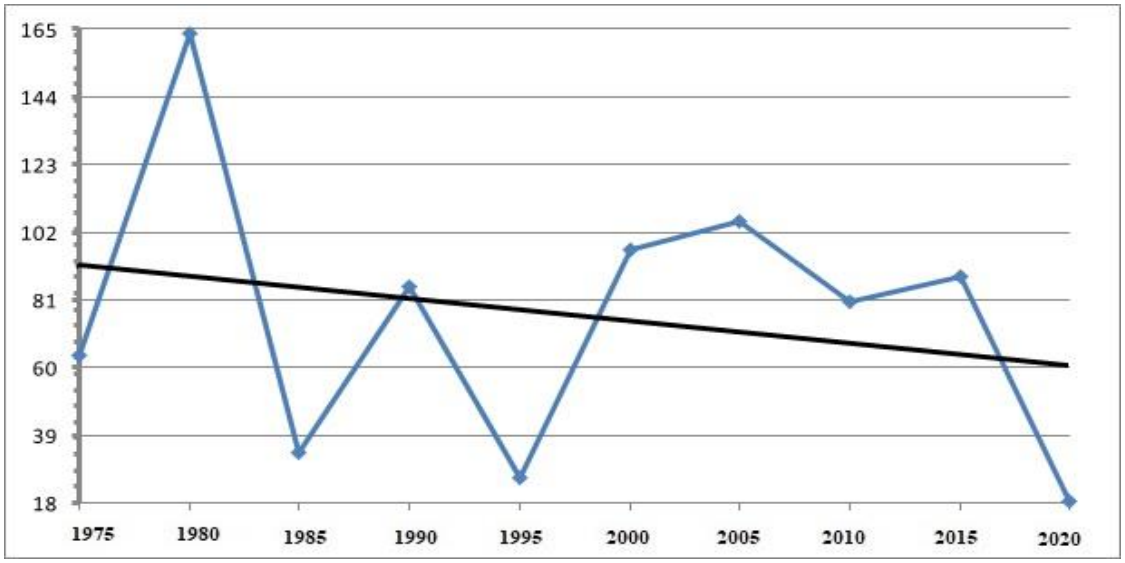


Fig. 10. Average annual precipitation for the autumn season in Baku, in mm.
(Huseynov, 2011; Mammadov & Gardashov, 2010)

The analysis of the trend of precipitation in the autumn season at the Baku station, indicates that precipitation decreased in the autumn months in those years. The lowest precipitation during these years was 12 mm in 1975, and in subsequent years it tended to increase. However, the maximum precipitation in the winter months for the Baku station was observed in 2010 and which was 110 mm. In subsequent years, precipitation intensity declined. The minimum value recorded in those years in 2020, which was 17 mm for the Baku station. (Figure 11).

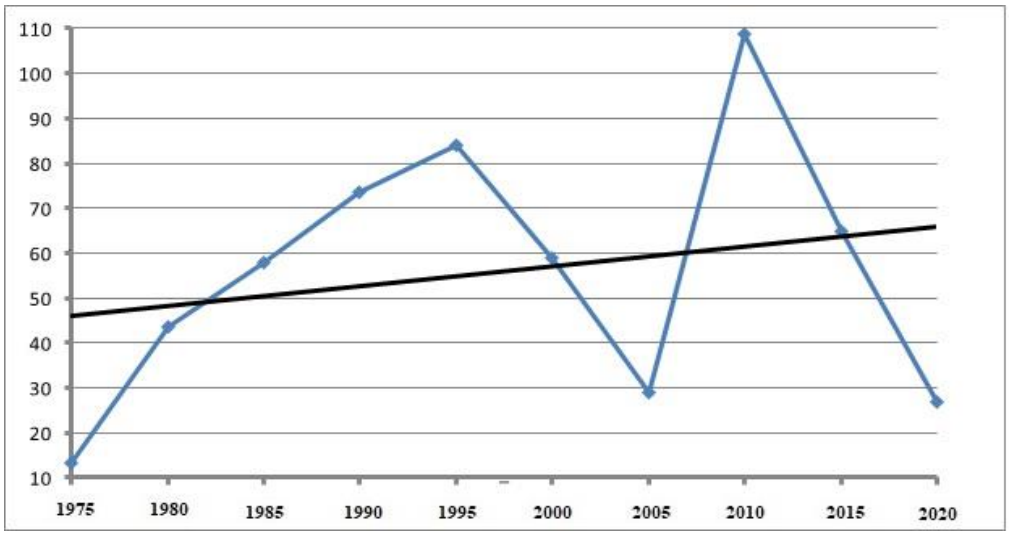


Fig. 11. Average annual precipitation for the autumn season in Baku, in mm.
(Huseynov, 2011; Mammadov & Gardashov, 2010)

The decrease in precipitation over the past 45 years on the Absheron Peninsula, including in the coastal zone, has led to a decrease in the degree of moisture. To determine the changes in the moisture coefficient in the study area, we examined the NDWI (Normalized Difference Water Index). Landsat satellite images were used in order to analyze this index (Gao, 1996). Thus, we used Landsat 4-5 satellite images to determine the NDWI for 1993, and for 2020, we used Landsat 8-9 satellite images (Figures 12, 13).

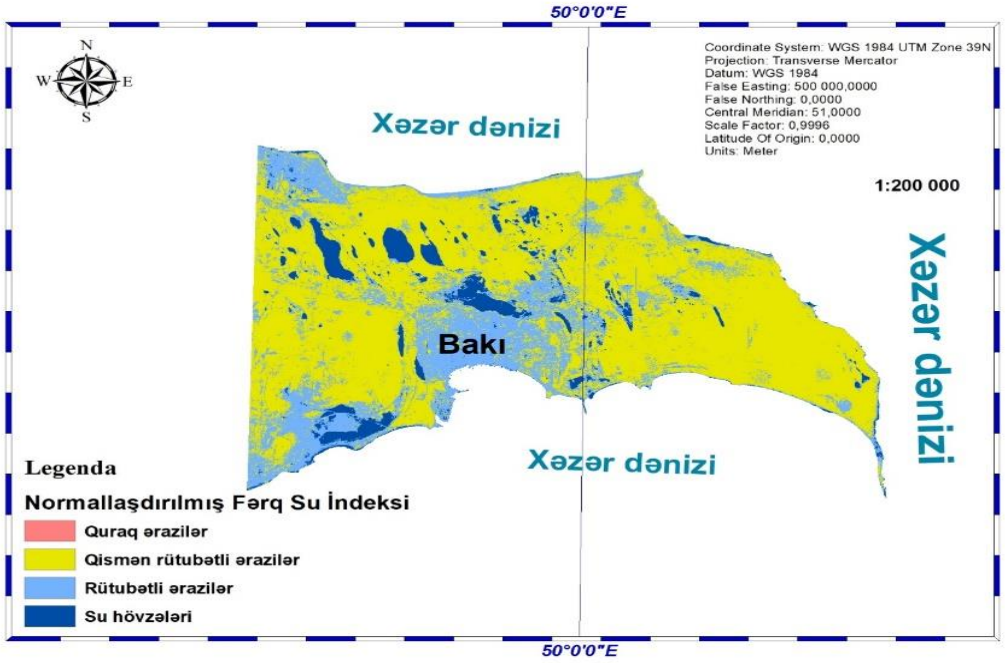


Fig. 12. NDWI (Normalized Difference Water Index) of the Absheron Peninsula for 1993

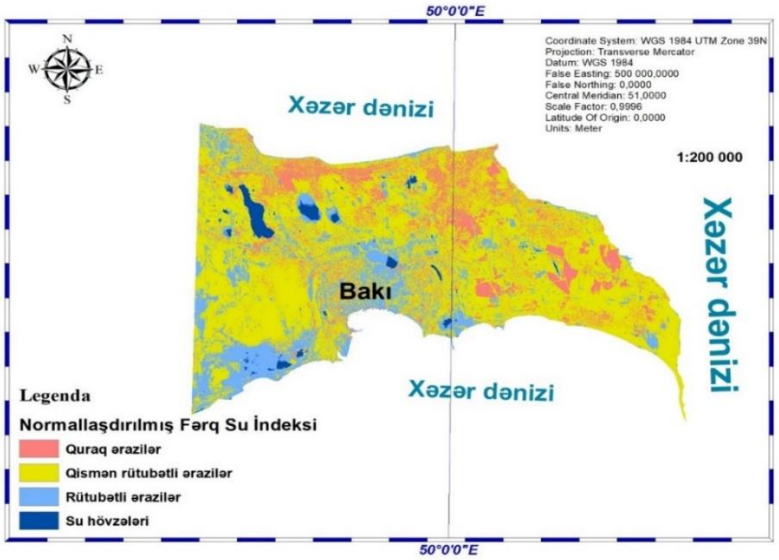


Fig.13. NDWI (Normalized Difference Water Index) map of the Absheron Peninsula in 2020

The Normalized Difference Water Index (NDWI), derived from annual composites of Landsat images, allows for the distinction between water bodies and other land surfaces (Hajiyeva & Ibrahimova, 2024). When combined with pixel analysis of each image, the index is a tool for highlighting whether a study area is submerged, as well as the degree of soil moisture. In addition, it is possible to estimate the area of open, i.e. unused, areas over time using the zonal histogram algorithm in QGIS on polygonal shapefiles representing the area surface (Amanova, 2022).

The same analyses were conducted on the yearly composites for the corresponding period to assess the impact of annual water level changes on the study area. As a result, an increase of 232 km^2 in the area of arid lands was indicated (Table 1). However, semi-humid areas decreased by 69 km^2, humid areas by 93 km^2, and water bodies by 70 km^2.

Table 1

NDWI values of the Absheron Peninsula for 1993–2020, km²

Moisture level	1993		2020	
	Km^2	in %	Km^2	in %
Arid areas	100	4,7	332	15,7
Semi-moist areas	1306	61,9	1237	58,6
Moist areas	501	23,7	408	19,3
Water bodies	203	9,7	133	6,4
Difference	2110	100	2110	100

Conclusion

The analysis of the results obtained from both the Mashtaga and Baku stations for the period 1957–2020 indicates a decrease in precipitation. According to the data from the Mashtaga station, the greatest decrease was recorded in the summer, while at the Baku station it occurred in the spring. This, in turn, had negatively affected the moisture availability of the Absheron Peninsula, which is located in a semi-desert dry-steppe climate. By analyzing the degree of moisture availability using the Normalized Difference Water Index (NDWI) from satellite images, we observe that arid areas increased by 9%, while semi-moist areas decreased by 3.3% and moist areas decreased by 4.4%. NDWI helps to determine which areas of agriculture are best suited for future development in areas with good moisture availability. This, in turn, can help in planning future research, assessing agriculturally suitable lands, and determining the degree of erosion and salinization.

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ABŞERON YARIMADASINDA YAĞINTILARININ AZALMASININ TORPAQLARIN RÜTUBƏTLƏNMƏ DƏRƏCƏSİNƏ TƏSİRİ

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Xülasə. Bu məqalədə 1975-2020-ci illər üçün landsat peyk məlumatlarından istifadə edərək bütün Abşeron yarımadasında yağıntı miqdarının dinamikası və onun kənd təsərrüfatına yararlı torpaqlara təsiri araşdırılmışdır. Müvafiq xətti tendensiyaların təhlili nəticəsində nəzərdən keçirilən dövrdə yarımadanın səthinə düşən yağıntılarda statistik cəhətdən əhəmiyyətli dəyişikliklərin olduğu aşkar edilmişdir. Lakin, 2005-ci ildən sonra illik yağıntıda kəskin azalma müşahidə olunur ki, bu da son illərdə dəniz səviyyəsinin əhəmiyyətli dərəcədə aşağı düşməsinin səbəblərindən biri ola bilər. Yağıntıların miqdarının azalması torpaqların rütubət balansının, su ehtiyatının pozulmasına və sonda kənd təsərrüfatının məhsuldarlığının aşağı düşməsinə gətirib çıxaracaqdır. Məqalədə yağıntıların miqdarının azalması dinamikasını və bitki örtüyünə təsirini təhlil etmək üçün NDWI (Normallaşdırılmış Fərqli Su İndeksi) əmsalından istifadə etmişik.

Açar sözlər: *Xəzər dənizi, iqlim dəyişikliyi, yağıntıların miqdarı, NDWI, səviyyə tərəddüdü, torpaq örtüyü*

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