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Research Article

Trend Analysis of Ground-Water Levels and The Effect of Effective Soil Stress Change: The Case Study of Konya Closed Basin

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Abstract

Determining the change of the groundwater level, which is one of the hydrological cycle parameters, is very important for the planning, the management of water resources, and economic development. The parametric and the non-parametric trend analyzes are performed to designate the alteration of the hydrological parameters in time. This study focused on trend analyses of the monthly average water levels (mm) of 10 observation stations (181, 182, 8185, 9431, 9434, 10472, 13314, 17171, 52258, 52564) in Konya Closed Basin (between 1978-2020). The parametric Linear Trend method and the non-parametric Mann-Kendall method were utilized in the analyses. In the study carried out at 95% of the confidence interval, it was found that the groundwater levels at all stations showed a statistically decreasing trend, and this trend gradually increased in recent years. At the station where the difference between the maximum and the minimum groundwater level is most noticeable, the effect of change of the groundwater level on the effective earth pressure was investigated. It has been observed that the gradual change of groundwater level occurring in all months of the year between certain years affects the effective stress balance in the soil environment.

Keywords: Effective Sail Pressure, Konya Closed Basin, Linear Trend, Mann-Kendall, Trend Analysis, Groundwater Level.

Yer Altı Su Seviyelerinin Trend Analizi ve Efektif Zemin Gerilmesi Değişimine Etkisi: Konya Kapalı Havzası Örneği

Öz

Hidrolojik çevrim parametrelerinden biri olan Yeraltı su seviyesinin değişiminin belirlenmesi su kaynaklarının planlanması, yönetilmesi ve ekonomik kalkınma için oldukça önemlidir. Hidrolojik parametrelerin zaman içinde değişimini belirlemek için parametrik ve parametrik olmayan trend analizleri yapılmaktadır. Bu çalışmada Konya Kapalı Havza'sında yer alan 10 adet (181, 182, 8185, 9431, 9434, 10472, 13314, 17171, 52258, 52564) YSS gözlem istasyonunun (1978-2020 yılları arası), aylık ortalama su seviyelerinin (mm) trend analizi yapılmıştır. Analizlerde parametrik yöntemlerden Lineer trend yöntemi ve parametrik olmayan Mann-Kendall yöntemi kullanılmıştır. Güven aralığının %95'lik kısmında gerçekleştirilen çalışmada, tüm istasyonlarda su seviyelerinin istatistiksel olarak azalan yönde eğilim gösterdiği, bu eğilimin son yıllarda giderek attığı tespit edilmiştir. Maksimum ve minimum yeraltı suyu seviyesi arasındaki farkın en belirgin olduğu istasyonda yeraltı suyu seviyesindeki değişimin etkin zemin basıncı üzerindeki etkisi araştırılmıştır. Belli yıllar arasında yılın tüm aylarında meydana gelen kademeli yeraltı su seviyesi değişiminin zemin ortamındaki efektif gerilmesi dengesini etkilendiği görülmüştür.

Anahtar Kelimeler: Efektif Zemin Basıncı, Konya Kapalı Havzası, Lineer Trend, Mann-Kendall, Trend Analizi, Yeraltı Su Seviyesi.

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1. Introduction

Water is one of the essential and beneficial substances not only for humans but also for all living things. Creatures provide the freshwater they need to survive from sources such as streams, lakes, seas, etc., or water collected in cavities or cracks in rocks. Humans collect surface water in various ways for their needs like drinking water, sanitation, agriculture, and livestock and transmit it to their community. In areas where there are no surface water formations such as rivers and lakes, the water requirement is met from groundwater. Therefore, especially in arid and semi-arid regions, searching and finding groundwater has been a matter of concern for humans since ancient times. In recent years, the importance given to groundwater research has come to the forefront with the increase in the utilizes of groundwater. Because of the increasing of the factories and the spreading of large areas with the development of the industry surface water resource, which is necessary for cities, have been decreased. This situation has been caused to obtain clean water from underground economically (Erguvanlı et al., 1987).

In a basin, if the amount of water taken from underground is more than the precipitation, flow, and leaking water in the basin, the amount of groundwater level decreases accordingly. Due to decreasing the level of groundwater, difficulties occur in the pumping used in water supply and pumping expenses increase. Besides, the deterioration of the quality of groundwater is seen as a side effect by the reason of the advancement of saltwater from the coast towards the inland regions. Salinity has been reduced agricultural production and agricultural activities and causes the termination of agricultural activities and production over time (Kavurmaci et al., 2010; Kendirli et al., 2005). Drought, desertification, and inefficiency of agricultural lands occur due to insufficient water access.

Hence, the level loss due to the aforementioned effects on the used groundwater level affects the stress equilibrium between soil piece and water. It is possible to occur local failure in soil because of deteriorating soil pressure. By increasing the groundwater level, floods may occur in the soils that become saturated quickly after rains. If dynamic loading like an earthquake happens in the case of groundwater level rise in soils with sand and silt, soil liquefication carries out through deterioration of equilibrium in the soil environment. As a result of the soil liquefication, heavy damages have been occurred by turning and sinking of the structure (Figure 1).

Figure 1. The soil liquefication (URL1, 2021)

Similarly, when the groundwater level falls, the pressure equilibrium on the soil deteriorates and sinkholes may form as a result of collapses (Figure 2) in the earth (Orhan, 2021). It is thought that the sinkhole formations that have recently occurred in the Karapınar Region in the Konya Closed Basin are associated with the fall of the groundwater level (Yılmaz, 2010). These abovementioned cases should be evaluated in terms of the equilibrium of soil stress because of happening formations which may be triggered by changed groundwater level.

Figure 2. A sinkhole in Karapınar (URL2, 2021)

To overcome these problems, it is important to know the depth, chemical properties, and change of groundwater and taking precautions for management and planning of water resources in the direction of obtained pieces of information about groundwater (Kara et al., 2004).

Many studies have been carried out depending on the level and characteristics of the groundwater level. Karataş et al. (2013) investigated the spatial and temporal variation of groundwater salinity and level in Menemen irrigation system using geostatistical methods integrated with GIS. Demir and Kılıç (2012) examined the salinity of 17 groundwater wells used for agricultural irrigation in the Aşağı Kelkit Basin. It is presented in the mentioned study that increasing salinity in groundwater has been reduced the yield of agricultural products.

Çelik et al.(2016) have been examined the water level change of the wells located in Suruç, Akçakale, and Ceylanpınar in Şanlıurfa with the graphs created according to the linear regression analyses. In their studies, they stated that the groundwater level decreased significantly due to unplanned agricultural activities and the groundwater level has been increased with the effect of the Southeastern Anatolia Project (GAP) which is included some regions of the study area. Mutlu (2010) investigated the changes in the water levels of the wells around Konya Karapınar by an outcoming graph that demonstrated the relationship between time and the trend of groundwater level.

Some studies conducted in recent years have identified serious variations in groundwater resources and the reasons for this change have been investigated (Bhattacharya et al., 2020; Bulduk et al., 2008; Chen et al., 2004; Chia et al., 2001; Dinka et al., 2013; Doğdu et al., 2007; Göçmez et al., 2008a; Göçmez et al., 2008b; Hoque et al., 2007; Jakeman et al., 2016; Konikow, 2011; Ma et al., 2005; Scibek et al., 2006; Ustun et al., 2010). The findings show that groundwater level changes stem from two main factors that the first one is climate change (Chen et al., 2004; Konikow, 2011; Scibek et al., 2006) and the second one is agricultural uses (Dinka et al., 2013). However, there are no studies on the investigation of groundwater level changes in the region by trend analysis as far as is known. For this reason, in this study, trend analysis of the monthly average water levels (mm) of 10 groundwater observation stations (wells) in Konya Closed Basin (181, 182, 8185, 9431, 9434, 10472, 13314, 17171, 52258, 52564) were performed. Analyzes were carried out at 95% of the confidence interval and the Linear Trend (LT) method and Mann-Kendall (MK) method were used. Besides, the groundwater level change that occurred every month of the year between 1978-2019 at station 8185, where the groundwater level is the most critical, was examined in terms of equilibrium in pore water pressure-effective soil stress.

2. Material and Method

2.1. Material

Konya Closed Basin (36 ° 51 'and 39 ° 29' north latitude and 31 ° 36 'and 34 ° 52' east longitude) is located in Turkey's Central Anatolia Region (Figure 3). Basin's area is 4,980,534 hectares, which corresponds to 7% of Turkey's total area. The basin was formed due to the air movements of an old riverbed rising in the middle of Anatolia. Due to its natural topography, it cannot discharge its waters into the sea. It is generally in the form of a flat plain (a height between 900-1,050 m) and forms the main part of the Central Anatolian Plateau. The plain is covered with limestone and volcanic mountainous areas. These mountains also prevent drainage into the sea. The Konya basin is a closed basin, as it can only discharge its waters into lakes, swamps, or semi-marshes (Yılmaz, Demir, & Sevimli, 2020).

The data of the monthly average groundwater level examined in the study were obtained from the General Directorate of State Hydraulic Works. Location information and well depths of the stations are given in Table 1. In Table 2, the statistical properties of the data are given. The long-term average groundwater levels are given in Figure 4.

Table 1. Statistical information for stations

No	Station Number	Max	Min	Mean	SD	SC	Period
1	181	-2.16	-39.1	-9.83	6.9	-1.17	67-20
2	182	-0.3	-29.1	-9.2	7.6	-0.8	67-20
3	8185	-29.9	-87.4	-52.2	15.1	-0.4	67-19
4	9431	-5.3	-39.4	-19.2	7.5	-0.6	67-20
5	9434	-25.5	-72.1	-44.6	12.3	-0.5	67-16
6	10472	-1.4	-35.2	-7.5	5.6	-0.9	67-17
7	13314	-38.3	-86.8	-53.51	13.13	-0.75	67-19
8	17171	-5.4	-41.7	-16.0	9.7	-0.9	67-20
9	52258	-16.8	-65.9	-31.3	13.9	-0.8	67-20
10	62564	-2.3	-45.5	-15.3	12.5	-0.9	67-20

* SD: Standard deviation, SC: Skewness Coefficient

Apart from the stations listed in Table 1, there are observation wells in the region. However, for trend analysis, it is necessary to have at least 30 years of data (Bayazıt, M., Önöz, 2008; Bayazıt, 1981). For this reason, station data with a shorter recording length could not be included in the study, considering that it was insufficient in terms of statistical significance. When the skewness coefficients of the stations are examined, it is seen that all stations are skewed to the left (SC<0). Although some stations requested data until 2020, the data available for the measurement period, not until 2020, were used for reasons such as drying, collapsing, or not being able to measure the relevant wells.

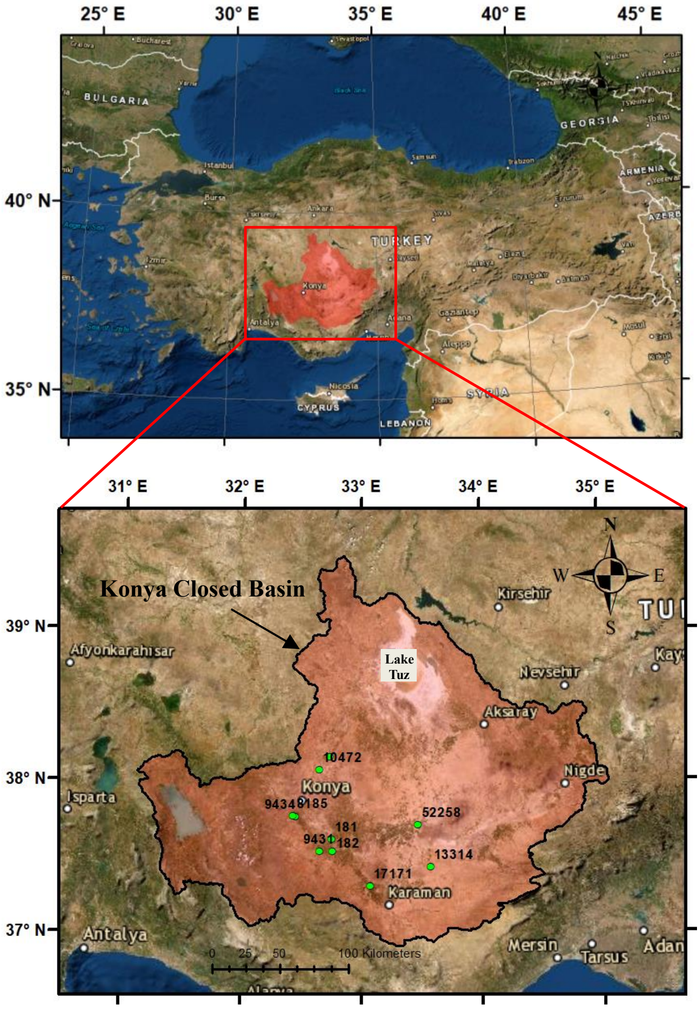

Figure 3. Study area

Table 2. Location information and well depths of stations

No	Station Number	Latitude (E)	Longitude (N)	Altitude (m)	Depth (m)
1	181	478036.2	4163883.2	1011.2	250
2	182	478756.61	4154870.7	1014.3	138
3	8185	449825.27	4181275.3	1050.2	145
4	9431	469336.39	4155060.8	1026.8	81
5	9434	451611.69	4180579.2	1044.5	175
6	10472	468802.71	4214738	1000.9	185
7	13314	550734.9	4143650.5	1034.8	119
8	17171	506261.84	4129275	1011.9	159
9	52258	541540	4174661	1024	173
10	62564	476660.57	4224054.2	988	83

When Table 2 is examined, the well at the highest elevation is the well numbered 8185. The well at the lowest point is the well numbered 62564 with a 988 m surface elevation. While the deepest well in the study area is the well numbered 181, the shallowest well is the well number 9431.

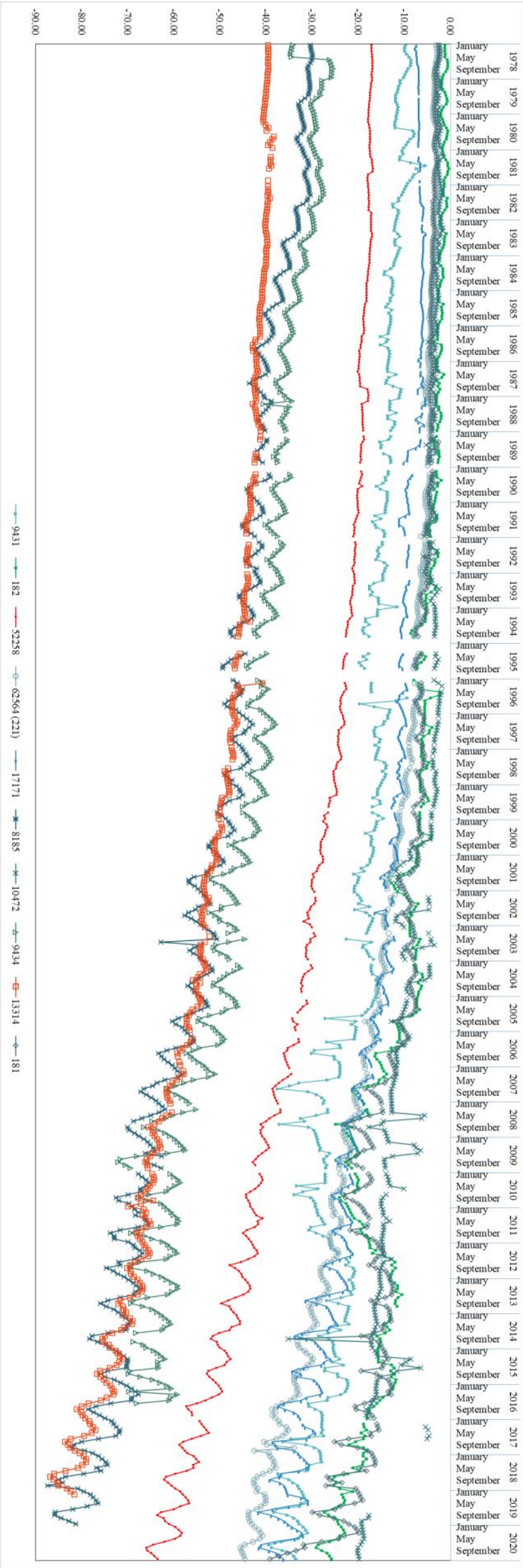

Figure 4. Long-term average groundwater level graphs

2.2. Method

Trend analyzes have been carried out to examine the change of underground water levels in Konya Closed Basin. The linear trend method, one of the parametric methods, and the Mann-Kendall method, one of the non-parametric methods, were used in the analyzes.

2.2.1. Mann-Kendall (MK)

For the MK test, first, "S", that is, the total value of the MK test statistics should be calculated. For this purpose, the data columns should be sorted from the first measurement date to the last measurement date (xi data columns sorted up to i = 1,…, N-1 and xj data columns sorted up to j = i + 1,…, N). Then, the xi data column is used as the beginning and the "S" value specified in Equation 2 is calculated using the other sorted xj and the signum function in Equation 1. As a result of these operations, the difference (xj − xi) of all data pairs and the sum of the number of positive and negative values are found (V. Demir et al., 2020; Yagbasan et al., 2020)

$$\operatorname{sgn}(x_j - x_i) = \begin{cases} 1; & if \quad x_j > x_i \\ 0; & if \quad x_j = x_i \\ -1; & if \quad x_j < x_i \end{cases} \tag{1}$$

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \operatorname{sgn}(x_j - x_i) \tag{2}$$

If the number of data is N is greater than 10, the variance is calculated for the series (Equation 3) and it is predicted to be approximately suitable for normal distribution. After the variance is calculated, the confidence interval value "Z" is calculated according to the "S" limits in Equation 4. The calculated Z value is compared with the standard Z values in the normal distribution table corresponding to the determined probability levels (Yu et al., 1993).

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{i=1}^{P'} t_i(t_i-1)(2t_i+5)}{18} \tag{3}$$

P 'in Equation 3; the number of connected groups in the series, ti; It refers to the number of observations connected to a series of length i.

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}}; & if \quad S > 0 \\ 0; & if \quad S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}}; & if \quad S < 0 \end{cases} \tag{4}$$

Whether there is a trend is determined by the Z values of the Normal distribution. The null hypothesis (H_0) is not accepted when the Z value calculated with the help of Equation 4 is greater than the $Z_{1-\alpha/2}$ value of the normal distribution corresponding to the α significance level. In other words, it is concluded that there is a trend in the time series. Similarly, when the Z value is less than the $Z_{1-\alpha/2}$ value in the distribution chart, it is accepted as (H_0). This shows that there is no statistically significant trend in the time series. If the (S) value is calculated as positive, it is concluded that there is an increasing trend in the investigated event, and a decreasing trend if it is calculated negative (Kendall, 1975; Mann, 1945).

2.2.2. Linear Trend (LT)

If one of the variables of the event being studied is dependent (y) and the other is independent (x), the relationship expressed as a function of y, x is called linear regression. The analysis performed to examine the relationship between the dependent variable and one or more independent variables is called regression analysis. With regression analysis, a cause-effect relationship can be found between variables, and what kind of relationship is between dependent-independent variables can be learned. In this study, groundwater level data is dependent, time (date) is an independent variable. With the regression analysis, the presence-absence of the relationship between these two variables, the strength of the relationship, and the change relative to each other can be learned. Trend analysis is used to determine the given direction of travel. Data may increase, decrease or persist over time. LT method is structurally based on regression analysis and is a parametric test that assumes that the data conform to a normal distribution. Tests the relationship between x and y variables, whether a linear trend exists (Karabulut et al., 2009). The slope of the "b" term of the curve in the form of yi = a + bxi obtained by this method, and the term "a" denotes the point where the curve intersects the y axis in the Cartesian coordinate system. "a" and "b" terms (Equations 5 and 6) are calculated as follows;

$$b = \frac{\sum_{i=1}^{N} x_i y_i - N\overline{xy}}{\sum_{i=1}^{N} x_i^2 - N\overline{x}^2} \tag{5}$$

$$a = \overline{y} - b\overline{x} \tag{6}$$

Whether there is a trend is determined by the t distribution and the t-test. The t value of the b value (slope) calculated with the help of Equation 5 is calculated (t_{cal}) and compared with a selected significance level (eg 95% or 99% confidence interval). If (t_{cal}) account value exceeds the accepted range, there is a trend and it is increasing or decreasing according to the sign. If it does not exceed ($-t_{critical} < t_{cal} < t_{critical}$), it is said that there is no trend (V. Demir, 2018; Yagbasan et al., 2020).

2.2.3. Effective Soil Stress

The soil without additional loading like filling, the weight of the structure, etc., or no influence of groundwater level exchange is defined as state as rest (elastic equilibrium). In this state, just stress due to soil mass and stable groundwater level are topics at the current point with certain soil depth. Effective soil stress influences carrying soil and causing displacement. The total stress in the soil environment with groundwater is obtained by using Equation 7 as the sum of the stress carried by the water and the stress carried by the soil grains (Das, 2019).

$$\sigma' = \sigma - u \tag{7}$$

Here, σ, σ', and u correspond to the total stress, effective soil stress, and pore water pressure respectively. In the determination of σ and u, Equations 8 and 9 have been employed, respectively.

$$\sigma = \gamma_{soil} H \tag{8}$$

$$u = \gamma_{water} H \tag{9}$$

H is the soil depth of the groundwater level considered in calculations. γ_{water} is unit weight and is taken as 9.81 kN/m^2. Because the unit volume of soil for station 8185 is not known exactly, the average value of γ_{soil} has been assumed as 18 kN/m^2 in calculations. Besides, the groundwater level change that occurred every month of the year between 1978-2019 at station 8185, where the groundwater level is the most critical, was examined in terms of equilibrium in pore water pressure-effective soil stress.

3. Results and Discussion

3.1. Results of Trend Analysis

In this section, the results of MK and LT methods are given in tables and interpreted. First, MK method Z account values are given in Table 3. According to MK method, the Z table or Z critical value is ± 1.96 at 95% of the confidence interval. Then LT method t account values are given in Table 4. According to the LT method, t critical values are ± 2.02 according to the number of data.

Table 3. MK trend analysis results

No	Period	181	182	8185	9431	9434
1	January	-6.96	-6.96	-7.95	-6.70	-7.10
2	February	-6.89	-7.02	-7.95	-6.93	-6.99
3	March	-7.01	-7.04	-7.89	-7.00	-6.85
4	April	-6.94	-6.99	-7.98	-6.73	-7.10
5	May	-6.99	-6.76	-7.98	-6.49	-7.03
6	June	-7.03	-6.79	-7.89	-6.12	-7.24
7	July	-7.07	-7.07	-7.92	-6.49	-7.21
8	August	-7.17	-7.05	-7.95	-6.70	-7.21
9	September	-7.14	-7.02	-8.01	-6.63	-7.28
10	October	-7.10	-7.12	-7.98	-6.53	-7.14
11	November	-7.03	-7.09	-7.95	-6.59	-7.14
12	December	-7.03	-7.10	-8.01	-6.44	-7.46
13	Annual	-7.14	-7.20	-7.98	-6.76	-7.17
14	Winter	-6.65	-7.05	-7.98	-7.00	-7.28
15	Spring	-7.01	-7.07	-8.01	-6.83	-7.14
16	Summer	-7.05	-7.05	-7.98	-6.53	-7.21
17	Autumn	-7.12	-7.07	-7.98	-6.66	-7.21
No	**Period**	**10472**	**13314**	**17171**	**52258**	**62564**
1	January	-6.35	-7.49	-6.82	-7.39	-7.33
2	February	-6.39	-7.49	-6.94	-7.37	-7.42
3	March	-5.99	-7.49	-6.87	-7.39	-7.23
4	April	-5.89	-7.53	-6.92	-7.37	-7.21
5	May	-5.57	-7.53	-6.71	-7.49	-7.23
6	June	-5.48	-7.46	-6.92	-7.42	-7.24
7	July	-5.87	-7.42	-6.92	-7.39	-7.28
8	August	-5.66	-7.42	-7.03	-7.39	-7.30
9	September	-5.64	-7.42	-7.03	-7.42	-7.31
10	October	-6.05	-7.46	-7.07	-7.39	-7.23
11	November	-6.39	-7.39	-7.14	-7.31	-7.31
12	December	-6.40	-7.33	-7.21	-7.24	-7.37
13	Annual	-6.07	-7.49	-7.10	-7.42	-7.31
14	Winter	-6.55	-7.53	-7.17	-7.42	-7.42
15	Spring	-5.80	-7.60	-6.94	-7.46	-7.26
16	Summer	-5.74	-7.46	-6.99	-7.39	-7.28
17	Autumn	-5.92	-7.49	-7.19	-7.39	-7.30

According to Table 3, it has been determined that all wells show a decreasing trend statistically in monthly, annual, and seasonal periods. While the decreasing trend is slower in well number 10472, it is faster in well number 8185 compared to other wells. As a result of the analysis, the min. Z calculated value is seen in station number 10472 in June, while the max. Z calculated value is seen in station number 8185 in September, December, and the spring season.

Table 4. LT trend analysis results

No	Period	181	182	8185	9431	9434
1	January	-13.39	-12.09	-34.54	-14.20	-18.69
2	February	-13.52	-12.42	-33.47	-14.88	-18.07
3	March	-14.10	-13.00	-32.19	-15.08	-17.55
4	April	-13.21	-13.38	-33.89	-14.15	-18.41
5	May	-13.31	-12.28	-36.82	-14.52	-19.37
6	June	-11.49	-11.81	-35.51	-12.68	-27.37
7	July	-11.55	-11.64	-39.57	-14.04	-23.34
8	August	-13.75	-12.20	-39.95	-14.29	-24.05
9	September	-12.05	-11.79	-39.24	-15.64	-23.48
10	October	-10.37	-12.20	-38.33	-15.35	-23.18
11	November	-9.06	-12.16	-34.00	-15.34	-22.28
12	December	-8.42	-12.53	-39.10	-14.68	-27.84
13	Annual	-12.22	-13.21	-39.14	-16.17	-23.82
14	Winter	-8.14	-13.47	-37.02	-16.03	-22.01
15	Spring	-13.75	-13.12	-34.85	-15.57	-19.03
16	Summer	-12.47	-12.08	-42.59	-14.29	-25.42
17	Autumn	-10.53	-12.07	-37.65	-15.61	-23.13
No	**Period**	**10472**	**13314**	**17171**	**52258**	**62564**
1	January	-10.26	-20.50	-22.22	-16.36	-14.51
2	February	-10.63	-19.90	-22.10	-15.78	-14.69
3	March	-9.98	-19.67	-23.08	-15.91	-14.90
4	April	-9.05	-20.60	-26.62	-16.22	-14.66
5	May	-8.03	-22.16	-26.11	-16.76	-14.90
6	June	-8.25	-22.18	-25.69	-16.66	-14.87
7	July	-8.10	-21.34	-25.90	-16.39	-14.77
8	August	-9.53	-20.87	-27.95	-16.23	-14.61
9	September	-7.32	-19.40	-25.36	-16.03	-14.59
10	October	-11.03	-20.27	-24.87	-16.06	-14.94
11	November	-11.55	-19.51	-27.35	-16.20	-14.77
12	December	-11.42	-18.63	-26.95	-16.17	-15.17
13	Annual	-10.47	-20.96	-27.15	-16.32	-14.86
14	Winter	-10.98	-20.39	-24.91	-16.26	-14.83
15	Spring	-9.47	-20.89	-26.22	-16.34	-14.85
16	Summer	-9.16	-21.59	-27.66	-16.43	-14.75
17	Autumn	-10.43	-19.93	-26.25	-16.11	-14.90

3.2. The Effect of Change in Ground Water Level on Effective Soil Stress

While the pore water pressure reduces with the decrease of groundwater level, and the pore water pressure affecting the soil grains increases with the increase of the groundwater level. For this reason, the observation station 8185, where the change in groundwater level is the most significant, has been selected in the investigation of the groundwater level effect on effective soil stress. Values of the total stress and the pore water pressure have been specified by considering about 30 years of groundwater levels for station 8185. In Figure 5, the change graph of the values of the effective soil stress according to each month is given for years between 1978-2019. In the dashed parts where the curve does not continue in the graph, measurement of the groundwater level has absent.

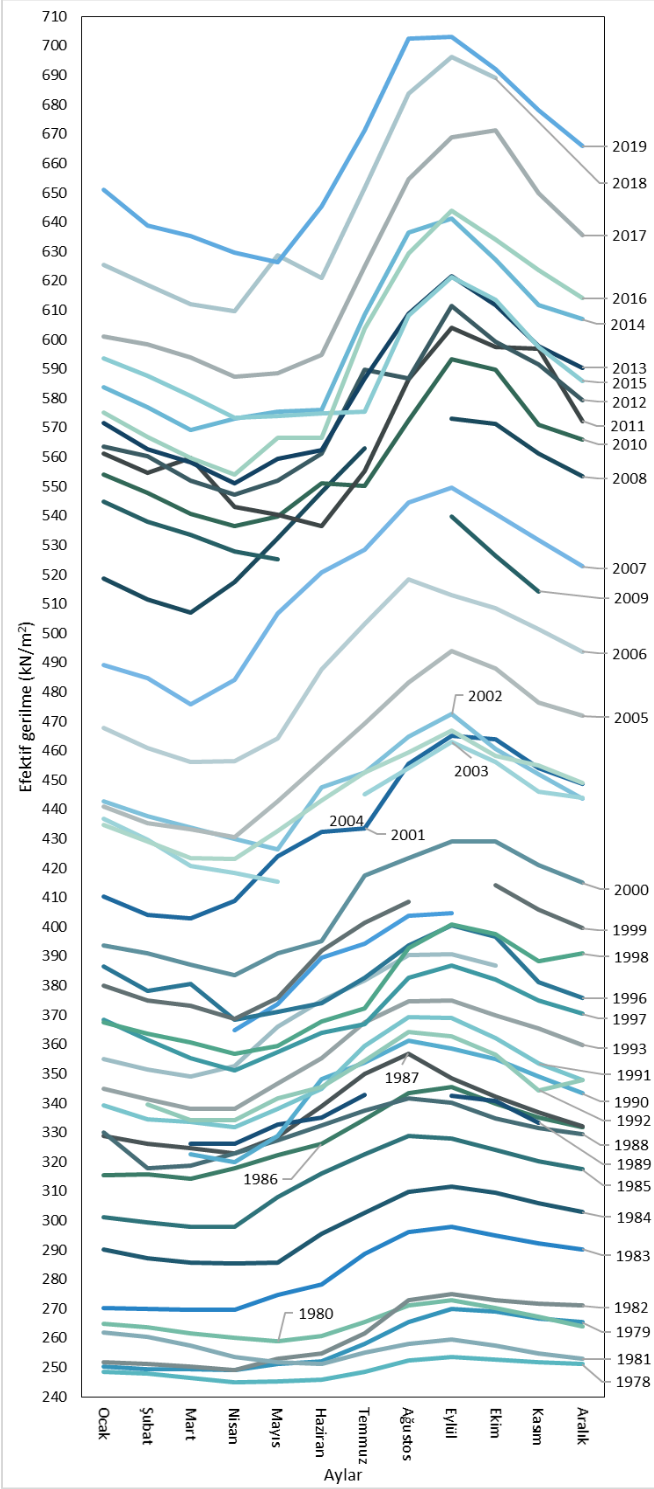

Figure 5. Time-dependent effective pressure changes at station 8185

When the graph given in Figure 5 is examined in terms of different years according to the seasons, the groundwater level decreases due to the increase in temperature and less precipitation in the summer months, and the values of the effective soil stress have reached their maximum values. When the effective stress value, which is defined as the stress carried by the soil grains, reaches a value greater than the bearing capacity of the soil, collapse may occur in the soil. This case may give information about the formation of a sinkhole which is usually happened in the arid summer months. During these months, groundwater is utilized extensively for the irrigation of agricultural products. When the groundwater level is raised with melting snow and precipitation in the spring season, it is observed that the minimum values of effective soil stress.

From the past to the present, it is seen that the effective soil stress changes have shown a fluctuating trend in the last twenty years and the decrease in the groundwater level has increased significantly. While the change of the effective soil stress by months in the graph is approximately linear in 1978, there is a significant increase and decrease in the values after the 1990s. This change occurred more sharply, especially between the years 2020-2010. Considering that the total decrease in groundwater level is approximately 50 m between 1978-2019, it is assumed as a reasonable outcome that the effective soil stress has such a moving trend.

3.3. Discussion

Konya Closed Basin has a semi-arid climate and the increase in the cultivation of agricultural products with high water need in addition to the drought in recent years has caused the number of thousands of deep irrigation wells in the basin to increase. As a result, various problems such as the lowering of the underground water level and the formation of new sinkholes, salinization in the soil, drying of many swamps and resources, and the decrease in the levels of the surrounding lakes occur (Demir et al., 2020; Yılmaz, 2010). When other studies in the region are examined, Doğdu et al. (2007) stated in their research that groundwater decreased approximately 0.2-0.9 m / year in Konya Plain between 1982 and 2007 and the water level decreases approximately 0.7 m / year occurred in Karapınar. Also, they stated that the decreases in groundwater level throughout the basin occurred in the dry period that was effective after 1980 in the region. Göçmez et al. (2008a) stated that 60% of the change in groundwater level in Konya and 40% in Karapınar is due to climatic variables, and the remaining percentage is related to excessive water extraction. Mutlu (2010) stated that Çumra, Konya, Ereğli, Karapınar, Sultanhanı, Obruk plains have 615 hm^3 / year safe water reserves, but in recent years the groundwater level has decreased seriously and worryingly, and as a result of this decrease, aquifers are disrupted and sinkholes are formed, he stated that sinkholes are approaching in increasing numbers from regions to urban areas and that besides economic losses, people and other living creatures living in the region are also in danger.

The findings show that the groundwater levels in Konya Closed Basin are decreasing with statistically significant trends and support previous studies.

4. Conclusions and Recommendations

In this study, trend analysis of groundwater level data of 10 wells in Konya Closed Basin, which have data between 1967-2020, was performed using MK and LT methods. In the analysis, the trends are made meaningful according to the critical values in 95% of the confidence interval.

When the results were examined, it was determined that statistically significant trends were observed in all wells according to MK and LT methods and the direction of these trends was negative. It has been observed that water levels have decreased dramatically in recent years. The decrease occurred at most in the well number 8185 (located in Konya province Meram district), followed by the well numbered 13314, 52258, 62564, 9434, 182, 181, 17171, 9431, and finally 10472.

With this study, different from the studies in the literature, the change of groundwater level has been analyzed by using trend analysis. Besides, the following recommendations have been made to solve the problems caused by the decrease in groundwater level in the region.

- Water management plans should be implemented with even more severe sanctions to control the groundwater level and prevent rapid level decreases.
- Illegal wells must be detected and illegal access to groundwater level must be prevented.
- Restrictions or prohibitions should be imposed on the cultivation of agricultural products with high water needs.
- Various chemical properties such as water levels and salinity in wells should be monitored. Measures should be taken with new water tanks that may affect areas where water levels decrease or water quality changes.
- The relationship of groundwater level with surface currents, lakes, potholes, and other meteorological parameters (such as temperature, precipitation, evaporation, wind speed, cloudiness rate) should be investigated and integrated basin management plans should be prepared.

Besides in this study, the effective soil stress changes have been investigated dependent time in this study by utilizing groundwater level values for the selected station. It has been observed that the groundwater level has decreased significantly in recent years. The descending and ascending behavior of the groundwater level affects the equilibrium between soil stress and water pressure of the soil environment which is the state as rest. The results show that the effective soil stress increases with the decrease of the groundwater level. Normally, the increase in the effective soil stress does not cause serious damage to the soil, but if this value is greater than the bearing capacity of the soil, deformations, and collapses may occur in the soil. For this reason, it is recommended to examine the changes in groundwater level taking into account the effect that they have on the soil environment.

References

Bayazıt, M., Önöz, B. (2008). *Taşkın ve Kuraklık Hidrolojisi*. Ankara, Türkiye: Nobel Basımevi.

Bayazıt, M. (1981). *Hidrolojide İstatistik Yöntemler*. İstanbul Teknik Üniversitesi matbaası, İstanbul.

Bhattacharya, R. K., Chatterjee, N. Das, & Das, K. (2020). An integrated GIS approach to analyze the impact of land use change and land cover alteration on ground water potential level: A study in Kangsabati Basin, India. *Groundwater for Sustainable Development*, *11*(April), 100399. doi: 10.1016/j.gsd.2020.100399

Bulduk, A., Horasan, Ö. R., Tekdere, M., & Solak, N. (2008). Konya Kapalı Havzasın Alt Havzasında Yeraltı Suyu ve Seviye Değişmeleri. *Konya Kapalı Havzası Yeraltı Suyu ve Kuraklık Konferansı*, 125–134.

Çelik, M. A., Doğantürk, İ. H., & Güney, İ. (2016). Şanlıurfa' nın Güneyindeki Ovalarda Yer Altı Su Algılama ve CBS Kullanılarak İncelenmesi. *6. Uzaktan Algılama-CBS*

Sempozyumu, 5–7.

Chen, Z., Grasby, S. E., & Osadetz, K. G. (2004). Relation between climate variability and groundwater levels in the upper carbonate aquifer, southern Manitoba, Canada. *Journal of Hydrology*, *290*(1–2), 43–62. doi: 10.1016/j.jhydrol.2003.11.029

Chia, Y., Wang, Y. S., Chiu, J. J., & Liu, C. W. (2001). Changes of groundwater level due to the 1999 Chi-Chi earthquake in the Choshui River alluvial fan in Taiwan. *Bulletin of the Seismological Society of America*, *91*(5), 1062–1068. doi: 10.1785/0120000726

Das, B. M. (2019). *Advanced Soil Mechanics, Third edition*. Retrieved from https://books.google.com/books?hl=tr&lr=&id=0cySDwAAQBAJ&oi=fnd&pg=PP15&dq=advanced+soil+mechanics+das&ots=6i3cnUrDcR&sig=w9yrLoDh_2xUXjkM3OfE35UFd28

Demir, S., & Kılıç, K. (2012). Erbaa Ovası Yeraltı Suyunun Tuzluluğunun Değerlendirilmesi Salinity Assessment of Groundwater in Erbaa Plain. *Iğdır Üni. Fen Bilimleri Enst. Der.*, *2*(4), 79–86.

Demir, V. (2018). *Karadeniz Bölgesi yağışlarının trend analizi*. Ondokuz Mayıs Üniversitesi , Fen Bilimleri Enstitüsü.

Demir, V., & Keskin, A. Ü. (2020). Water level change of lakes and sinkholes in Central Turkey under anthropogenic effects. *Theoretical and Applied Climatology*, *142*(3–4), 929–943. doi: 10.1007/s00704-020-03347-5

Dinka, M. O., Loiskandl, W., Fürst, J., & Ndambuki, J. M. (2013). Seasonal behavior and spatial fluctuations of groundwater levels in long-term irrigated agriculture: The case of a sugar estate. *Polish Journal of Environmental Studies*, *22*(5), 1325–1334.

Doğdu, M. Ş., Toklu, M. M., & Sağnak, C. (2007). Konya Kapalı Havzası'nda Yağış ve Yeraltı Suyu Değerlerinin İrdelenmesi. *I. Türkiye İklim Değişikliği Kongresi*, 394–402.

Erguvanlı, K., & Erdoğan, Y. (1987). *Yeraltısuları Jeolojisi (Hidrojeoloji)*. İstanbul Teknik Üniversitesi, Maden Mühendisliği Fakültesi Ofset Matbaası.

Göçmez, G., Dıvrak, B., & Galena, İ. (2008). Konya Kapalı Havzası'nda Yeraltı Suyu Seviyesinin Değişiminin Tespiti Özet Raporu. *WWF*.

Göçmez, G., Genç, A., & Karakoca, A. (2008). Konya Kapalı Havzası Yeraltısuyu Seviye Değişiminin İstatistiksel Değerlendirilmesi. *Konya Kapalı Havzası Yeraltı Suyu ve Kuraklık Konferansı*, 98–107.

Hoque, M. A., Hoque, M. M., & Ahmed, K. M. (2007). Declining groundwater level and aquifer dewatering in Dhaka metropolitan area, Bangladesh: Causes and quantification. *Hydrogeology Journal*, *15*(8), 1523–1534. doi: 10.1007/s10040-007-0226-5

Jakeman, A. J., Barreteau, O., & Rinaudo, R. J. H. J. (2016). Integrated Groundwater Management. In Integrated Groundwater Management. doi: 10.1007/978-3-319-23576-9

Kara, T., & Arslan, H. (2004). Bafra Ovası sulama alanında taban suyu ve tuzluluk araştırması. *Bafra Ovası Sulama Alanında Taban Suyu ve Tuzluluk Araştırması.*, 89–96.

Karabulut, M., & Cosun, F. (2009). Kahramanmaraş İlinde Yağışların Trend Analizi. *Coğrafi Bilimler Dergisi*, *7*(1), 65–83.

Karatas, B. S., Camoglu, G., & Olgen, M. K. (2013). Spatio-temporal trend analysis of the depth and salinity of the groundwater, using geostatistics integrated with GIS, of the menemen irrigation system, Western Turkey. *Ekoloji*, *47*(86), 36–47. doi: 10.5053/ekoloji.2013.865

Kavurmaci, M., Altaş, L., Kurmaç, Y., Işik, M., & Elhatip, H. (2010). Evaluation of the Salt Lake effect on the ground waters of Aksaray-Turkey using geographic information system. *Ekoloji*, *77*, 29–34. doi: 10.5053/ekoloji.2010.775

Kendall, M. G. (1975). *Rank Correlation Methods*. London: Chtirles Griffin.

Kendirli, B., Cakmak, B., & Ucar, Y. (2005). Salinity in the southeastern anatolia project (GAP), Turkey: Issues and options. *Irrigation and Drainage*, *54*(1), 115–122. doi: 10.1002/ird.157

Konikow, L. F. (2011). Contribution of global groundwater depletion since 1900 to sea-level rise. *Geophysical Research Letters*, *38*(17), 1–5. doi: 10.1029/2011GL048604

Ma, J. Z., Wang, X. S., & Edmunds, W. M. (2005). The characteristics of ground-water resources and their changes under the impacts of human activity in the arid Northwest China - A case study of the Shiyang River Basin. *Journal of Arid Environments*, *61*(2), 277–295. doi: 10.1016/j.jaridenv.2004.07.014

Mann H B. (1945). "Non-parametric tests against trend." *Econometrica*, *13*(3), 245–259.

Orhan, O. (2021). Monitoring of land subsidence due to excessive groundwater extraction using small baseline subset technique in Konya, Turkey. *Environmental Monitoring and Assessment.* (in press) DOI : 10.1007/s10661-021-08962-x

Scibek, J., & Allen, D. M. (2006). Modeled impacts of predicted climate change on recharge and groundwater levels. *Water Resources Research*, *42*(11), 1–18. doi: 10.1029/2005WR004742

URL1. (2021). *https://www.movea.com.tr/zeminde-sivilasma-nedir/#:~:text=Zemin%20s%C4%B1v%C4%B1la%C5%9Fmas%C4%B1%2C%20yeralt%C4%B1%20su%20seviyesi,siltli%20zeminler)%20g%C3%B6r%C3%BClen%20bir%20olayd%C4%B1r.* Retrieved from https://www.movea.com.tr/zeminde-sivilasma-nedir/#:%7B~%7D:text=Zemin

URL2. (2021). *https://www.haberturk.com/misir-ve-yonca-gibi-su-tuketen-urunler-obruk-olusumunu-hizlandiriyor-2156941*.

Ustun, A., Tusat, E., & Yalvac, S. (2010). Preliminary results of land subsidence monitoring project in Konya Closed Basin between 2006-2009 by means of GNSS observations. *Natural Hazards and Earth System Science*, *10*(6), 1151–1157. doi: 10.5194/nhess-10-1151-2010

Yagbasan, O., Demir, V., & Yazicigil, H. (2020). Trend Analyses of Meteorological Variables and Lake Levels for Two Shallow Lakes in Central Turkey. *Water*, *12*(2), 414. doi: 10.3390/w12020414

Yılmaz, C. B., Demir, V., & Sevimli, M. F. (2020). Trend analysis of maximum flow values of Konya closed basin. *2nd International Eurasian Conference on Science, Engineering and Technology (EurasianSciEnTech 2020)*, 594–607.

Yılmaz, M. (2010). Karapınar Çevresinde Yeraltı Suyu Seviye Değişimlerinin Yaratmış Olduğu Çevre Sorunları. *Ankara Üniversitesi Çevrebilimleri Dergisi*, *2*(2), 145–163. doi: 10.1501/Csaum

Yu, Y.-S., Zou, S., & Whittemore, D. (1993). Non-parametric trend analysis of water quality data of rivers in Kansas. *Journal of Hydrology*, *150*(1), 61–80. doi: 10.1016/0022-1694(93)90156-4