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Landslide susceptibility mapping of Tokat (Turkey) province using weight of evidence and random forest

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ABSTRACT

Landslides are one of the important disasters that have negative effects on people. In this study, the Landslide Susceptibility Map of Tokat (Turkey) province was produced. Slope classes, elevation classes, land use classes, geology classes, aspect classes and proximity to fault lines classes were used during the study. The Weight of Evidence method was applied to determine the relationship between the classes of the parameters and the landslide events. Random Forest method was used to determine the weights between parameters. Weighted Overlay operation was applied to the classified and weighted map data using ArcGIS program. As a result of the process, the data were divided into 5 classes and the Landslide Susceptibility Map was produced. When susceptibility classes are examined, it was seen that 92,42% of the old landslide events occurred in high and very high classes.

1. Introduction

Disasters are events that cause material and moral damages in the society they affect and cause great problems in terms of the consequences they cause in the flow of daily life. The landslides can be defined as the downward movement or sliding of parts such as soil and rocks, under the influence of gravity or external factors such as earthquakes and continuous rains (AFAD, 2014).

When examining the negative effects caused by landslides, it is necessary to know the spatial distribution and inventory information of past landslides. Using the available inventory data, landslide susceptibility analysis, risk and hazard values can be determined (Van Westen et al., 2008). Landslide susceptibility analysis, which reveals areas susceptible to possible future landslides, reveals the desire for any landslide to take place (Guzzetti et al., 2006). Landslide susceptibility maps are of great importance in predicting future landslides and providing land use planning (Basara et al., 2020).

Weight of Evidence (WoE) and Random Forest (RF) were used as methods in the study. Slope, Aspect, Elevation, Geology, Land Use, Proximity to fault lines were used as materials. As a result of this study, the landslide susceptibility map divided into 5 sub-sections was produced. The produced map was compared with the previous landslide events in the region. According to this comparison, an accuracy of 92,42% was found.

In this study, the Landslide Susceptibility Map of Tokat (Turkey) Province was produced. Location Map given in Figure 1.

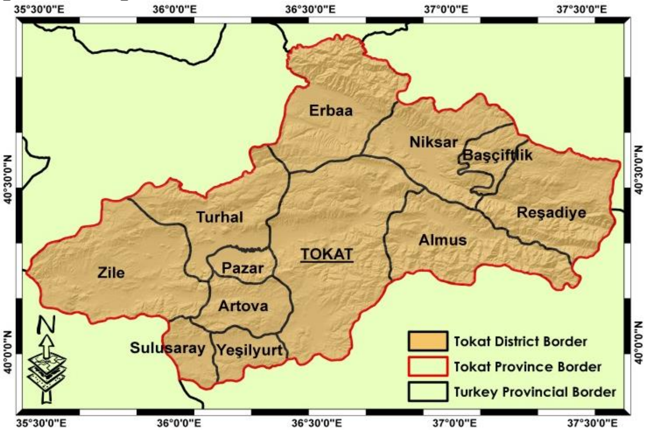

Figure 1. Location Map

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This study is an extended version of the paper presented at the 2nd IGD symposium (Basara & Sisman, 2021).

2. Method

Although there are many landslide susceptibility map applications in the literature (Aleotti & Chowdhury, 1999; Lee & Talib, 2005; Tetik Biçer, 2017), there is no consensus on the methods and parameters used in these applications. There are a lot of landslide susceptibility analysis methods like Frequency Ratio, Analytical Hierarchy Process, Weight of Evidence, Logistic Regression, Fuzzy Logic and Artificial Neural Networks (Basara et al., 2021).

In this study, the Weight of Evidence method which is one of the statistical methods and the Random Forest Algorithm which is one of the machine learning methods, were used together.

2.1. Weight of evidence method (WoE)

The Weight of Evidence method has been mathematically expressed by Van Westen et al. (2003) and Regmi et al. (2010). In this study, the weights of the subcategories of the factors affecting the landslide were determined using the equation 1-3 (Regmi et al., 2010; Ozdemir & Altural, 2013).

$$W+ = \ln[(A1/(A1 + A2)) / (A3/(A3 + A4))] \quad (1)$$

$$W- = \ln[(A2/(A1 + A2)) / (A4/(A3 + A4))] \quad (2)$$

$$C = (W +) - (W-) \quad (3)$$

In the equation, A1 refers to the landslide areas in a selected subcategory, A2 refers to the total landslide areas outside the selected category, A3 refers to the areas with no landslides in the selected category, and A4 refers to the total landslide-free areas other than the selected category. While A1 + A2 refers to the total landslide areas, A3 + A4 refers to the total landslide-free areas in the study area. (Regmi et al., 2010).

The difference between the W + and W- weights is called the contrast of the weights (C). The C value shows the final positional relationship between the landslide event and the forecast variable. A value equal to zero indicates that the subcategory of the factor causing the landslide is not important for the analysis. Positive contrast indicates a positive positional relationship, negative contrast indicates the opposite (Ozdemir & Altural, 2013).

2.2. Random forest algorithm (RF)

Random Forest Method is one of the collective learning algorithms based on using many decision tree models together to solve a specific classification and regression problem (Breiman, 2001). The algorithm is based on the principle of combining the estimates made by each of the decision trees that make up the forest and making the final decision for the relevant sample in the process of estimating a sample with an unknown class label (Kuncheva & Whitaker, 2003).

The general formula of the Random Forest algorithm is defined as in Equation 4. Since the algorithm produces K number of decision trees, the predicted value (P) is given by the average of the predicted values (T) in all trees (Costa et al., 2020). Generalization error in Random Forest algorithm is defined as in Equation 6. The "x and y" values here are the landslide conditioning factors showing the x-y space and the probability above mg and are defined as in Equation 5-6. The "I" values here measure the extent to which the average number of votes in random vectors exceeds the average vote for any other output for correct output (Masetic et al., 2016).

$$P = \frac{1}{K}\sum_{k=1}^{K} T \quad (4)$$

$$\mathrm{GE} = P_{x,y}\ (\ \mathrm{mg}\ (\mathrm{x,y}) < 0\ ) \quad (5)$$

$$\mathrm{mg}(\mathrm{x,y}) = \mathrm{av_k I}(\mathrm{h_k}(\mathrm{x}) = \mathrm{y}) - \mathrm{max}_{\mathrm{j} \neq \mathrm{y}}\mathrm{av_k I}(\mathrm{h_k}(\mathrm{x}) = \mathrm{j}) \quad (6)$$

3. Material

There is no standard for the parameters to be used in landslide susceptibility analysis studies. Therefore, the parameters may differ depending on the area to be studied. When the parameters used in the landslide susceptibility analysis were analyzed statistically, the rates in Table 1 were obtained (Tetik Biçer, 2017).

Table 1. Usage Rates of Parameters

Landslide Parameters	Usage Rate (%)	Landslide Parameters	Usage Rate (%)
Slope	86,47	Land Use	46,62
Lithology	67,29	Curvature	40,60
Aspect	59,77	Fault Lines	28,57
Elevation	55,64	NDVI	24,06
Drainage Density	50,75	Soil Groups	23,68

GIS is important for collecting and processing geographic data of objects. Transforming data into geographic information with geographic analysis and viewing geographic data helps to plan activities (Basara et al., 2021).

In this study, Slope, Aspect, Elevation, Geology, Land Use, Proximity to Fault Lines and Landslide Inventory Map were used. The parameters to be used in the study were mapped with the help of ArcGIS. Maps of the material are given in Figure 2-8.

3.1. Slope

Slope is the main stability parameter that affects shear and normal stresses on the surface. It is more common among researchers that the slope angle is directly proportional to the landslide risk (Karslı et al., 2009; Baeza & Corominas, 2001). Statistical analysis of slopes causing landslides should be made and a decision should be made accordingly (Basara, 2021).

3.2. Aspect

Aspect can be mentioned on the slopes of the same object facing different directions. Aspect is the parameter that shows the direction of the land surface relative to the sun's rays. The direction in which the tangent plane is facing at any point on the surface (Dağ, 2007).

3.3. Elevation

Topographic features vary with altitude. Elevation causes topographical differences in the study area. Altitude controls temperature and vegetation. Landslides, rock and soil properties and other geotechnical parameters are associated with altitude values (Guzzetti et al., 2009).

3.4. Geology

Landslide events are directly related to soil properties such as strength, permeability and hardness (Baeza & Corominas, 2001). Since the geological features will give important information about the landslide sensitivity of the study area, it should be evaluated correctly (Guzzetti et al., 1999).

3.5. Land use

The land use can be the reason of landslide events. Thus, the relationship between the areas like artificial, agricultural, forest, wetlands and water with sparse and dense vegetation and landslides should be evaluated (Basara et al., 2021).

3.6. Proximity to faults

Some landslides can be associated with fault lines areas because of weakness of the material surrounding them. The more buffer zone should be created, taking into account the different proximity for proximity to fault lines. (Wachal & Hudak, 2000). Some inferences can be made as a result of field observations. In this context, it was determined that most of the landslides occurred in regions very close to the faults. (Gökceoglu & Aksoy, 1996).

3.7. Landslide inventory

Landslide inventory is defined as data containing information about the location, type, activity and physical characteristics of landslides in a region. The information about past landslides are obtained as the first step of landslide susceptibility. It is thought that the future landslides may occur under conditions similar to the past landslides. (Varnes, 1984).

For this reason, the Landslide Inventory Map of the study area was created by using the landslide events 1950 - 2021.

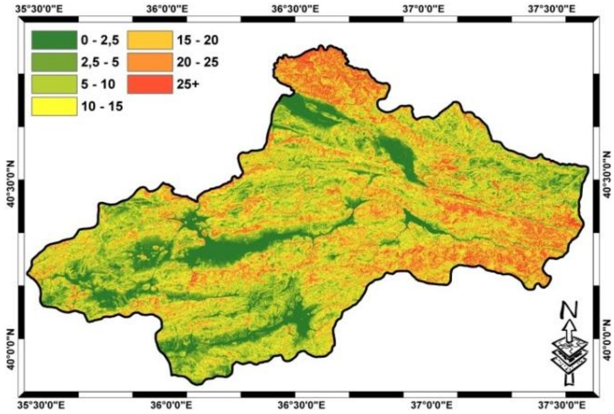

Figure 2. Slope Map

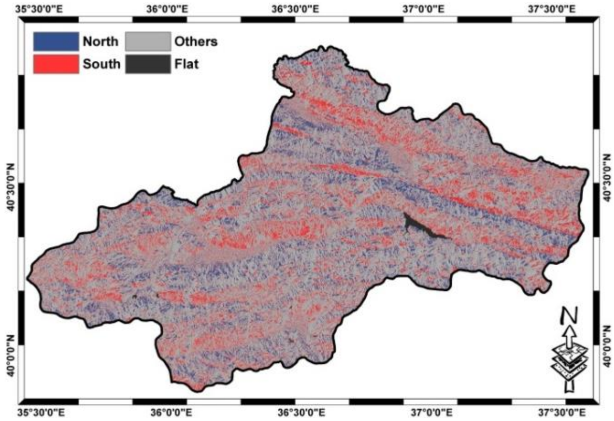

Figure 3. Aspect Map

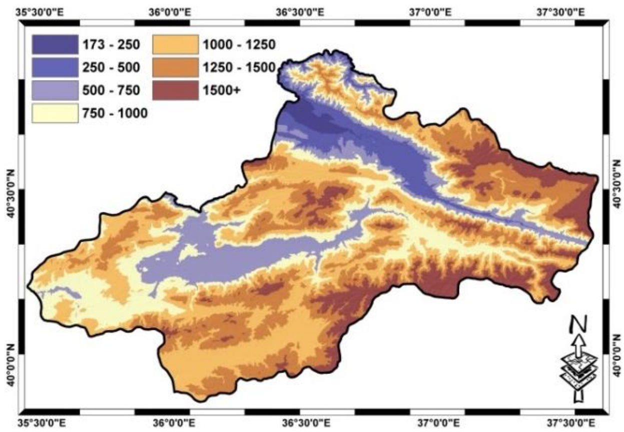

Figure 4. Elevation Map

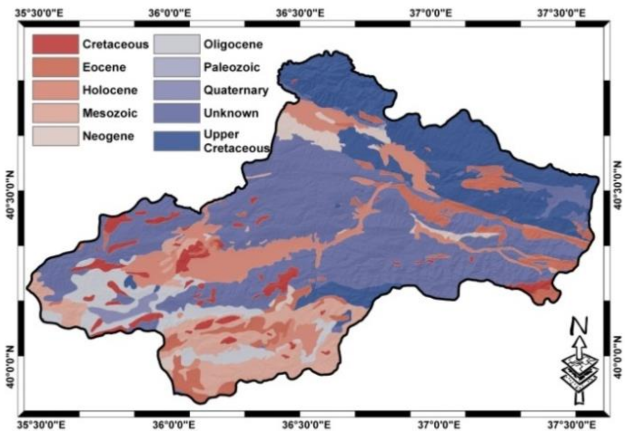

Figure 5. Geology Map

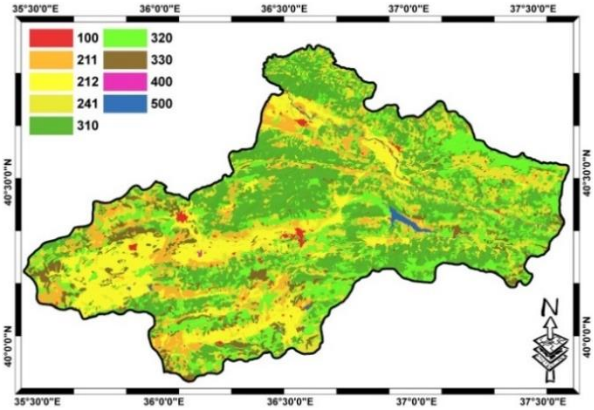

Figure 6. Land Use Map

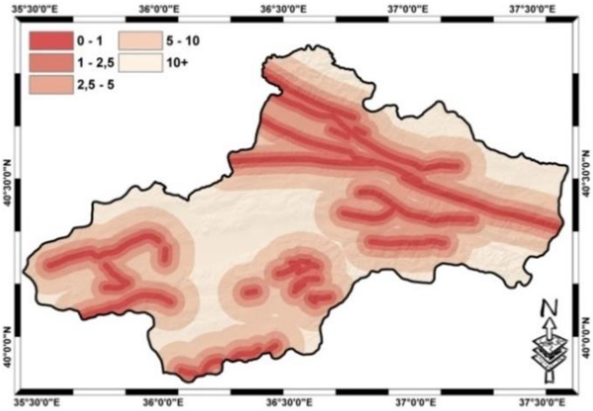

Figure 7. Proximity to Fault Lines Map

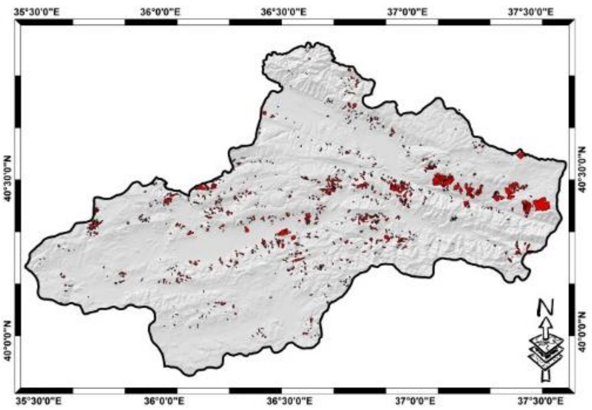

Figure 8. Landslide Inventory Map

4. Results

In this study, the landslide susceptibility map was obtained in two stages. In the first part, the Weight of Evidence (WoE) method was applied. Landslide impact priorities of parameter subclasses were determined. In the second part, the Random Forest (RF) algorithm is applied. Woe data was used in the application of RF. In this way, the priorities of the parameters among each other were determined.

The relationship of the maps with the landslide inventory map was determined using the Weight of Evidence (WoE) Method. The maps were reclassified according to the results of the analysis. The data obtained according to the Weight of Evidence (WoE) method are given in table 2-7.

Table 2. Aspect Classes

Attribute	Landslide area	Total area	WoE
North	46,76 km^2	1317,89 km^2	0,0945
South	48,81 km^2	1306,85 km^2	0,1566
Others	232,66 km^2	7349,36 km^2	-0,1310
Flat	0,28 km^2	43,39 km^2	-1,6471

Table 3. Geology Classes

Attribute	Landslide area	Total area	WoE
Cretaceous	6,07 km^2	407,14 km^2	-0,8300
Eocene	38,78 km^2	783,26 km^2	0,4744
Holocene	8,54 km^2	1043,15 km^2	-1,5004
Mesozoic	10,74 km^2	971,05 km^2	-1,1804
Neogene	3,36 km^2	250,12 km^2	-0,9289
Oligocene	3,52 km^2	649,02 km^2	-1,8865
Paleozoic	0,26 km^2	3,43 km^2	0,8992
Quaternary	0,06 km^2	72,22 km^2	-3,7744
Unknown	155,76 km^2	3944,05 km^2	0,3386
Upper Cretaceous	101,68 km^2	1897,02 km^2	0,6777

Table 4. Slope Classes

Attribute	Landslide area	Total area	WoE
0 – 2,5 degree	4,31 km^2	1220,36 km^2	-2,3784
2,5 – 5 degree	17,53 km^2	1169,98 km^2	-0,8736
5 – 10 degree	94,69 km^2	2432,80 km^2	0,2415
10 – 15 degree	104,96 km^2	2119,40 km^2	0,5816
15 – 20 degree	66,70 km^2	1510,13 km^2	0,3752
20 – 25 degree	26,93 km^2	880,08 km^2	-0,0781
25 degree+	13,39 km^2	684,72 km^2	-0,5610

Table 5. Elevation Classes

Attribute	Landslide area	Total area	WoE
173 – 250 m	0,14 km^2	131,32 km^2	-3,5079
250 – 500 m	5,52 km^2	528,47 km^2	-1,2061
500 – 750 m	38,39 km^2	1240,21 km^2	-0,0677
750 – 1000 m	103,66 km^2	1811,46 km^2	0,7679
1000 – 1250 m	116,33 km^2	2936,22 km^2	0,2896
1250 – 1500 m	46,35 km^2	2324,58 km^2	-0,6265
1500 m+	18,16 km^2	1048,20 km^2	-0,7091

Table 6. Land Use Classes

Attribute	Landslide area	Total area	WoE
CORINE.100	4,14 km^2	135,52 km^2	-0,0759
CORINE.211	39,25 km^2	808,52 km^2	0,4526
CORINE.212	12,31 km^2	1337,34 km^2	-1,4041
CORINE.241	134,27 km^2	1919,02 km^2	1,1182
CORINE.310	77,45 km^2	3105,39 km^2	-0,3883
CORINE.320	49,65 km^2	1966,29 km^2	-0,3261
CORINE.330	11,25 km^2	669,71 km^2	-0,7213
CORINE.400	0,00 km^2	2,38 km^2	-11,2991
CORINE.500	0,31 km^2	72,31 km^2	-2,0788

Table 7. Proximity to Fault Lines Classes

Attribute	Landslide area	Total area	WoE
0 - 1 km	29,84 km^2	1094,26 km^2	-0,2117
1 - 2,5 km	52,81 km^2	1563,53 km^2	0,0358
2,5 - 5 km	91,08 km^2	2112,37 km^2	0,3746
5 - 10 km	84,38 km^2	2829,21 km^2	-0,1346
10 km+	70,61 km^2	2421,09 km^2	-0,1573

The Random Forest (RF) Algorithm was used to determine the stature of the parameters relative to each other. In the implementation of this process, the data obtained as a result of the Weight of Evidence (WoE) method was used. The data obtained as a result of the Random Forest (RF) Algorithm are given in Table 8.

Table 8. Random Forest Data

Parameters	Variable İmportance	Standard Deviation	Weight
Land Use	66,909	0,261	27 %
Aspect	10,073	0,036	4 %
Slope	40,407	0,172	16 %
Proximity to Faults	35,912	0,243	14 %
Geology	42,681	0,392	17 %
Elevation	52,508	0,215	21 %

Finally, the Landslide Susceptibility Map was produced by processing the data with Weighted Overlay analysis. The map produced was reclassified 5 as very low, low, medium, high and very high. Landslide susceptibility map is given in Figure 9.

5. Discussion

The created landslide susceptibility map was compared with the parameter classes used in the study. Risk values of parameter classes are given in Table 9.

Table 9. Risk Values of Parameter Classes

Parameters	Classes	Class Risk (%)	Class Area (%)
Slope	0 – 2,5 degree	12,49	12,18
	2,5 – 5 degree	45,14	11,66
	5 – 10 degree	74,53	24,31
	10 – 15 degree	84,92	21,14
	15 – 20 degree	87,10	15,08
	20 – 25 degree	82,15	8,81
	25 degree+	66,69	6,82
Elevation	173 – 250 m	0,40	1,30
	250 – 500 m	32,79	5,27
	500 – 750 m	53,79	12,37
	750 – 1000 m	75,92	18,08
	1000 – 1250 m	78,13	29,30
	1250 – 1500 m	67,97	23,21
	1500 m+	66,74	10,48
Aspect	North	68,45	13,18
	South	68,56	13,06
	Others	67,90	73,33
	Flat	0,80	0,43
Land Use	CORINE.100	41,43	1,35
	CORINE.211	76,66	8,08
	CORINE.212	5,45	13,35
	CORINE.241	93,81	19,15
	CORINE.310	81,41	31,01
	CORINE.320	70,90	19,63
	CORINE.330	47,25	6,69
	CORINE.400	0,00	0,02
	CORINE.500	0,59	0,72
Geology	Cretaceous	39,83	4,07
	Eocene	84,59	7,82
	Holocene	19,31	10,41
	Mesozoic	38,86	9,73
	Neogene	39,08	2,49
	Oligocene	18,85	6,50
	Paleozoic	100,00	0,03
	Quaternary	0,15	0,72
	Unknown	88,46	39,37
	Upper Cretaceous	88,51	18,84
Proximity to Fault Lines	0 - 1 km	60,49	10,91
	1 - 2,5 km	64,09	15,61
	2,5 - 5 km	72,25	21,09
	5 - 10 km	67,79	28,26
	10 km+	69,50	24,13

Table 9 is continued.

When the data in the table are examined, it has been determined that slope, elevation, land use and geology parameters are important for the study area. Parameter subclasses were evident in the creation of different risk groups.

It has been determined that the aspect parameter is not important for the study area as there is no distinctiveness in the subgroups. In future studies, the parameter can be made meaningful by examining it in different classes.

The fact that the risk ratios in the subgroups were very close to each other showed that the parameter of proximity to the fault lines was not important for the study area. In future studies, the parameter can be made meaningful by examining it with different proximity classes.

6. Conclusion

The areas and rates of the landslide susceptibility classes are given in Table 10.

Table 10. Landslide Susceptibility Classes

	Landslide area (km^2)	Total area (km^2)	Landslide incident (%)	Total area (%)
Very Low	0,00	187,79	0,00	1,88
Low	0,82	878,77	0,25	8,78
Medium	24,13	2160,46	7,33	21,58
High	125,91	4905,13	38,25	48,99
Very High	178,35	1880,26	54,18	18,78

When susceptibility classes are examined it was seen that 92,42% of the old landslide events occurred in high and very high class, 7,33% occurred in middle class and 0,25% occurred in low and very low class.

In the spatially analysis of landslide events, it was seen that the sensitivity classes are examined spatially, high-risk areas constitute 67,77% of all areas, medium-risk areas constitute 21,58% of all areas and low-risk areas constitute 10,65% of all areas.

Method and parameter selection for landslide susceptibility analysis is a step that needs attention. In the result of working, it was determined that the sub-classification step of the parameter is as important as the parameter selection in landslide susceptibility analysis studies.

As a result, it is possible to say the following. Susceptibility mapping is very important to prevent material and moral losses that may occur due to disasters.

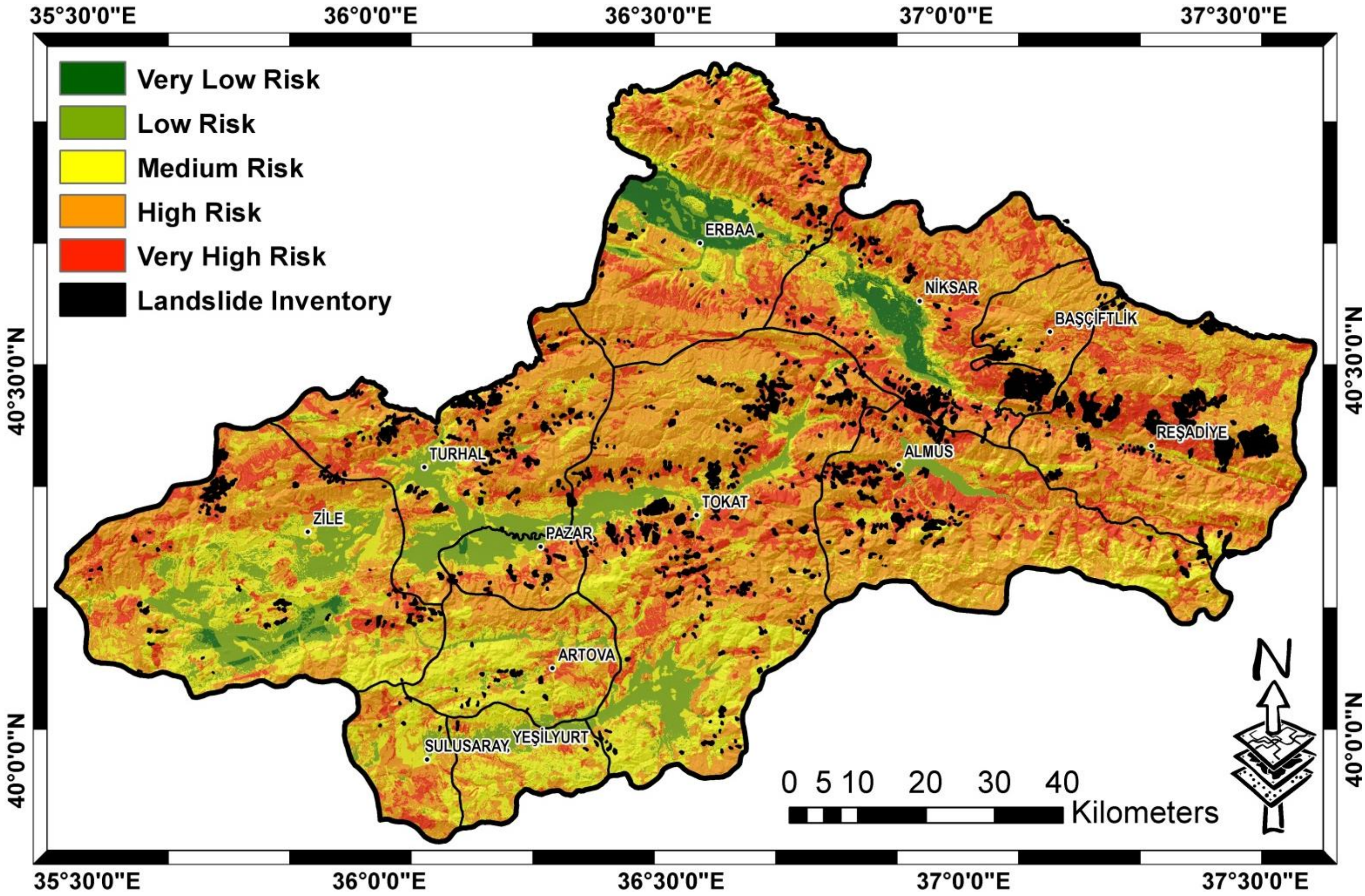

Figure 9. Landslide Susceptibility Map

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Author Contributions

1st Author: Conceptualization, Methodology, Software, Data Curation, Writing-Original Draft Preparation, Validation, Visualization
2nd Author: Investigation, Reviewing and Editing

Statement of Conflicts of Interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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Determination of precipitation trend by time series: A case study Erbaa plain

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Trend Analysis
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Mann Kendall Test
Sen's Slope Test

ABSTRACT

Changes in precipitation occur due to global or local climate changes. Studying this change is very important for human life. Rainfall is very important in meeting essential needs such as agricultural activities and clean water resources. Therefore, trend analysis in precipitation data is important. In this study, in order to examine whether there is a trend in the precipitation data of Erbaa Plain (Turkey), first homogeneity test was performed and then the standard precipitation index was calculated. The calculated data were analyzed using the Mann-Kendall test and Sen's Slope test. Monthly precipitation data for 40 years covering the years 1981-2020 were used in the study. Precipitation data were analyzed according to 90% confidence interval. Trends were detected in January and September in monthly precipitation series

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1. Introduction

Meteorological events on earth have unfixed feature. Therefore, the size and consequences of meteorological changes cannot be easily predicted (Coskun, 2019). The meteorological data changes are a complex natural hazard that causes drought and affects ecosystems and society in many ways. In order to minimization the drought effects, the drought risk should be assessed and the water resources management strategies should be developed (Beden et al., 2020).

Meteorology; is the science of the atmosphere. Pressure, temperature, humidity, wind, cloudiness, precipitation, insolation, evaporation are meteorological parameters. These combine at different rates to determine the climate of a region and are affected by factors such as latitude, land and seas, altitude, and vegetation (Mercan, 2016).

The most important common subject in hydrology, meteorology and hydrometeorology branches is precipitation. In general, the stages before and after the formation of precipitation in the atmosphere are of interest to meteorology, the situation after it reaches the earth's surface, hydrology, and the necessary evaluations and calculations for the preparation of water projects are also of interest to hydrometeorology (Gençer et al., 2005).

Changes in precipitation in a residential area can lead to important problems affecting human life. Change has significant effects on clean water resources and agricultural activities. Efficient use and control of water is provided by the correct evaluation and analysis of the meteorological data. In order to meet the needs, the management of water resources that change depending on time and quantity parameters is very important. Thus, the precipitation data should be examined on the presence of any trend (Yuce et al., 2017). While, the continuous decrease in precipitation values, disasters can be observed such as drought and desertification, the continuous increase precipitation values, disasters such as landslides and floods are seen. Therefore, trend analysis and disaster risk maps in rainfall data have great importance (Beden et al., 2020; Basara et al., 2021).

Various analysis methods such as time series, regression analysis and machine learning are used in the analysis of meteorological data. In this study, one of the analysis methods, time series methods were used.

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The sequences formed by ordering the observations for any event according to time are called time series. The process of generating new data from observed values is called time series analysis.

Time series have served different purposes with different models in many studies. Some of those: In his application, Sfetsos compared different forecasting methods based on time series analysis and hourly average wind speed observations (Sfetsos, 2000), In his application, Sarıyer estimated the demand in emergency services using ARIMA models with time series analysis (Sarıyer, 2018), Yavuz, in his application, investigated the effect of exports on economic growth in Turkey by using time series and Granger causality test (Yavuz, 2012).

The precipitation, known as most important meteorological data, was selected as study topic.

In this study, precipitation analysis of the Erbaa Plain, which has a high importance in terms of agricultural activities in Tokat province, located in the Middle Black Sea Region, was performed using Mann Kendall and Sen slope test.

This study is an extended version of the paper presented at the 2nd IGD symposium (Gunes et al., 2021).

2. Material and Method

2.1. Material

Wide flat areas that are not divided by valleys and are low compared to their surroundings are called plains. There are tectonic plains, delta plains and karst plains in Turkey. Especially tectonic plains are common. In the Black Sea region, there are tectonic and delta plains. Erbaa plain is one of the tectonic plains in the Black Sea region. It is a very fertile plain with an altitude of 250m and soils rich in humus. The application area given in Figure 1.

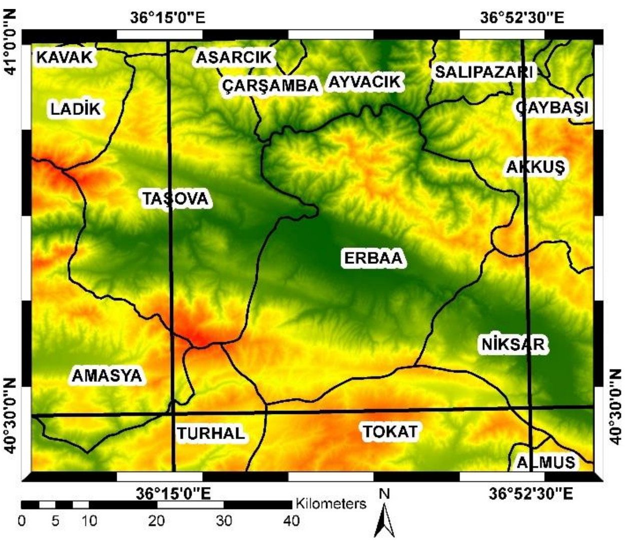

Figure 1. The Application Area

The precipitation data were taken from the NASA Langley Research Center (LaRC) POWER project. Monthly precipitation data for the 40-year period covering the years 1981-2020 were obtained from the website of the project. POWER Release 901 not only builds upon the data portal established with Release 8, but adds more recent data releases from NASA's GEWEX SRB Release 4, CERES SYN 1-deg, and FLASHFlux Version 4A. The data/parameters in POWER Release 901 are provided on a global grid with spatial resolutions equal to the input data. That resolution is 1.0° latitude by 1.0° longitude for the radiation data sets and ½° latitude by ⅝° longitude for the meteorological data sets. The POWER solar data is based upon satellite observations from which surface insolation values are inferred. The meteorological parameters are based upon the MERRA-2 assimilation model. The data of application area given in Figure 1 was created using geographic information systems.

2.1.2. Standard normal homogeneity test (SNHT)

The Standard Normal Homogeneity test (SNHT) method is used in the tests of many climatic and hydrological sizes (Alexandersson, 1986). A point "c" from the analyzed series is divided into two by reference and Equation 1 is calculated with the help of Equation 2 If the change occurs at a 'h' point, T (c) reaches its maximum value at the point c = h. The test statistic is as in Equation 3. If the test value exceeds the table value, it is rejected. In this case, it is decided that the data are not homogeneous.

$$T(c) = c.\bar{z_1}^2 + (n-c).c.\bar{z_2}^2 \quad c = 1, \ldots, n \quad (1)$$

$$\bar{z_1} = (\sum_{i=1}^{c} \frac{y_i - \bar{y}}{\sigma})/c \text{ ve } \bar{z_2} = (\sum_{i=1+c}^{n} \frac{y_i - \bar{y}}{\sigma})/(n-c) \quad (2)$$

The test statistic is as in Equation 3. If the test value exceeds the table value, it is rejected. In this case, it is decided that the data are not homogeneous.

$$T_0 = max_{1 \le c \le n} T(c) \quad (3)$$

2.1.2. Standard precipitation index (SPI)

The Standard Precipitation Index (SPI) was proposed in 1993 and is used to identify and monitor drought in regions with varying climate (Mckee et al., 1993). If the data is in a normal distribution, the difference of precipitation from the mean can be divided by the standard deviation to determine the abnormalities in the regions. SPI account are calculated using Equation 4. The Standard Precipitation Index (SPI) values are classified according to Table 1.

$$SPI = \frac{(x_i - x_i^{ort})}{\sigma} \quad (4)$$

Table 1. SPI Classification

SPI Value	Drought Category
≥ 2	Extremely Humid
1.5 to 1.99	Very Humid
1.0 to 1.49	Moderately Humid
0.50 to 0.99	Lightly Humid
-0.49 to 0.49	Normal
-0.99 to -0.50	Lightly Drought
-1.0 to -1.49	Moderate Drought
-1.5 to -1.99	Very Drought
≤ -2	Extreme Drought

2.2. Methods

Time series analysis is the process of generating new data with various data and models. It serves many different areas. Tests for the detection of increasing or decreasing trends in meteorological time series can be classified as parametric and non-parametric tests. Parametric methods are methods based on assumptions such as normal distribution of data, homogeneity of variances and linearity. Non-parametric methods, on the other hand, are the methods used in cases where the data do not show normal distribution and there are missing data. Meteorological data do not always show a normal distribution due to missing data and significant seasonality. For this reason, the use of non-parametric methods in the analysis of climatological data is more appropriate than parametric methods. Considering all these, Mann Kendall test was applied to determine the magnitude and direction of the trend, and Sen's Slope test was applied to determine the trend of the trend (Özdel, 2020).

2.2.1. Mann Kendall test

The Mann-Kendall method is a non-parametric method that is processed according to the presence or absence of change in parameters in a time series (Mann, 1945; Kendall, 1975). It is determined whether there is a trend in the data using Mann Kendall test (Besel & Tanir Kayıkçı, 2019). In this method, the order of the data is compared (Gilbert, 1987). One of the advantages of the test is that the data does not need to any distribution.

Mann-Kendall test is calculated using Equation 5 and Equation 6.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (5)$$

$$sgn(x_j - x_k) = \begin{cases} 1 \ (x_j - x_k) > 0 \\ 0 \ (x_j - x_k) = 0 \\ -1 \ (x_j - x_k) < 0 \end{cases} \quad (6)$$

The variance calculation of the test statistic with a normal distribution is calculated using Equation 7.

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \quad (7)$$

In order to determine the significance of the test and probability function are calculated using Equation 8-9.

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \quad (8)$$

$$F(Z) = \frac{1}{2\pi} e^{\frac{-z^2}{2}} \quad (9)$$

2.2.2. Sen's slope test

The direction and size of the trend in the data are determined using the Sen's Slope test (Sen, 1968). If there is a linear trend in the time series, the actual slope (change in unit time) can be determined using a nonparametric method. This method can be applied to records that are not affected by data errors or extreme values and where there are missing values (Yu et al., 1993).

The median is calculated using Equation 10 in Sen's Slope test.

$$Q_i = \frac{(x_j - x_k)}{(j-k)} \quad (10)$$

If the number of data (N), is an odd or even, Equation 11 and 12 are applied, respectively.

$$Q = Q_{(N+1)/2} \quad (11)$$

$$Q = \frac{1}{2}\left[Q_{N/2} + Q_{(N+2)/2}\right] \quad (12)$$

3. Results

In the first stage of the study, the Standard Homogeneity Test (SNHT) was applied to determine the suitability of the values in the data set for analysis. Then SPI values were calculated for drought classification. The Mann-Kendall test was applied to determine the direction of trends and statistical significance levels in the data series. In the last stage, Sen's Slope test was applied to determine the trend directions. This process was made for monthly and annual total precipitation series. The work flow chart of the study is given in Figure 2.

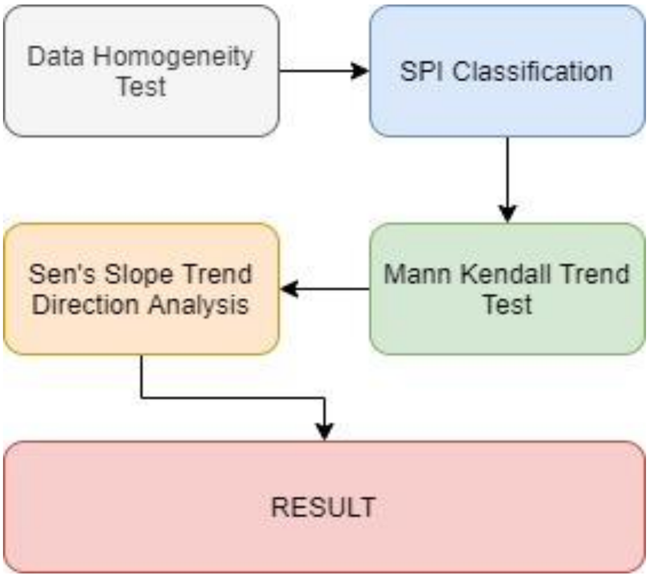

Figure 2. Flow Chart

Homogeneity testing was done using the R-Studio program. Results are given in Table 2. It was found that the data were homogeneous and suitable for analysis.

Table 2. Homogeneity Analysis Result

P-value	alpha	SNHT
0.466	0.05	Homogeneous

According to Table 2, it was decided that the data were homogeneous since P-value selected significance value (0.05). The calculation and classification of SPI values of application data are calculated using Equation 4 and Table 1. The results are given in Table 3.

Table 3. Annual SPI Classes

Year	SPI Class	Year	SPI Class
1981	Lightly Drought	2001	Normal
1982	Lightly Humid	2002	Normal
1983	Normal	2003	Normal
1984	Moderate Drought	2004	Moderately Humid
1985	Moderate Drought	2005	Lightly Humid
1986	Very Drought	2006	Moderate Drought
1987	Normal	2007	Normal
1988	Lightly Humid	2008	Normal
1989	Moderate Drought	2009	Extremely Humid
1990	Moderate Drought	2010	Lightly Humid
1991	Lightly Humid	2011	Moderately Humid
1992	Normal	2012	Very Humid
1993	Moderate Drought	2013	Very Drought
1994	Normal	2014	Normal
1995	Normal	2015	Lightly Drought
1996	Lightly Humid	2016	Moderately Humid
1997	Normal	2017	Lightly Drought
1998	Lightly Humid	2018	Normal
1999	Moderately Humid	2019	Lightly Drought
2000	Lightly Humid	2020	Very Drought

From the Table 3, Extremely, Very, Moderately and Lightly Humid in %35, Normal in %32.5, Lightly, Moderate, Very Drought in %32.5was observed. There was no SPI Class in the Extreme Drought class.

Mann-Kendall Test results of the monthly total precipitation data set are given in Table 4.

Table 4. Monthly Mann Kendall Trend Analysis Results

Months	MK-z Tau	MK-P Value	MK Hypo-thesis
January	0.297	0.007	Refuse
February	-0.108	0.328	Accept
March	0.162	0.142	Accept
Aprıl	-0.136	0.217	Accept
May	0.151	0.169	Accept
June	0.181	0.100	Accept
July	0.001	0.991	Accept
August	0.003	0.981	Accept
September	0.196	0.075	Refuse
October	-0.090	0.415	Accept
November	-0.110	0.316	Accept
December	0.074	0.499	Accept

Sen's Slope Test results for the monthly total precipitation data set are given in Table 5.

Table 5. Monthly Sen's Slope Trend Analysis Results

Months	Sen's Slope	Sen's Type of Trend
January	0.033	Increase
February	-0.007	No Trend
March	0.018	Increase
Aprıl	-0.016	Decrease
May	0.013	Increase
June	0.017	Increase
July	0.000	No Trend
August	0.000	No Trend
September	0.018	Increase
October	-0.010	Decrease
November	-0.018	Decrease
December	0.007	No Trend

Trend charts obtained as a result of the analysis are given in Figure 3-14.

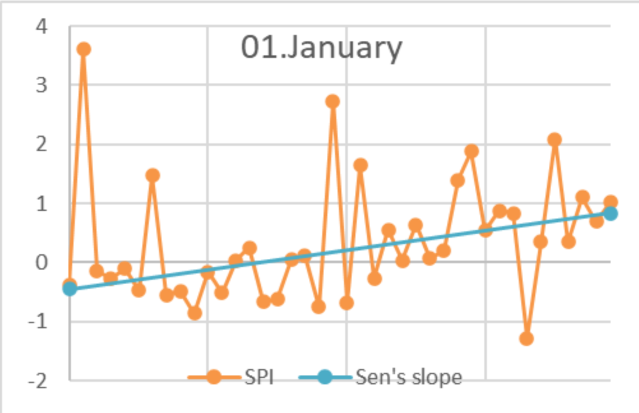

Figure 3. January Trend Graph

MK-z Tau value was calculated as 0.297 in January data. Since the calculated P value of 0.007 was lower than 10% significance level, the alternative hypothesis was accepted. Sen's Slope value was calculated as 0.033.

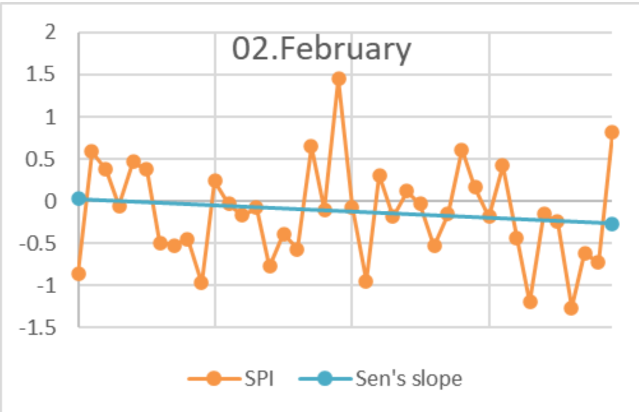

Figure 4. February Trend Graph

MK-z Tau value was calculated as -0.108 in February data. Since the calculated P value of 0.328 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as -0.007.

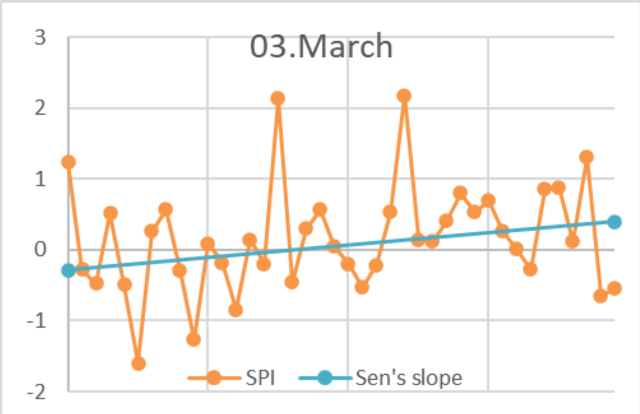

Figure 5. March Trend Graph

MK-z Tau value was calculated as 0.162 in March data. Since the calculated P value of 0.142 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.018.

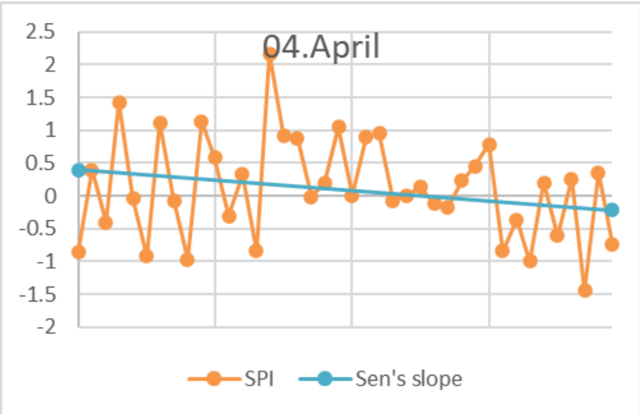

Figure 6. April Trend Graph

MK-z Tau value was calculated as -0.136 in April data. Since the calculated P value of 0.217 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as -0.016.

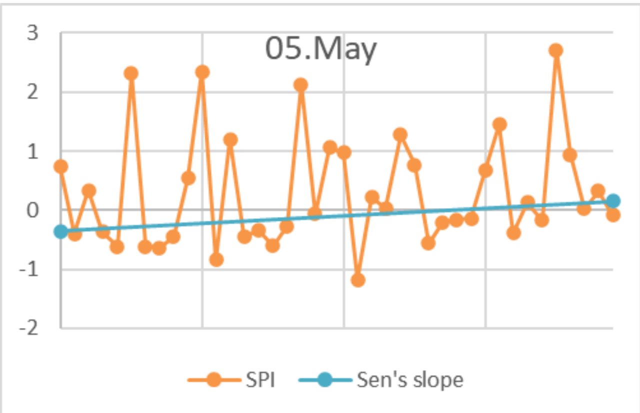

Figure 7. May Trend Graph

MK-z Tau value was calculated as 0.151 in May data. Since the calculated P value of 0.169 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.013.

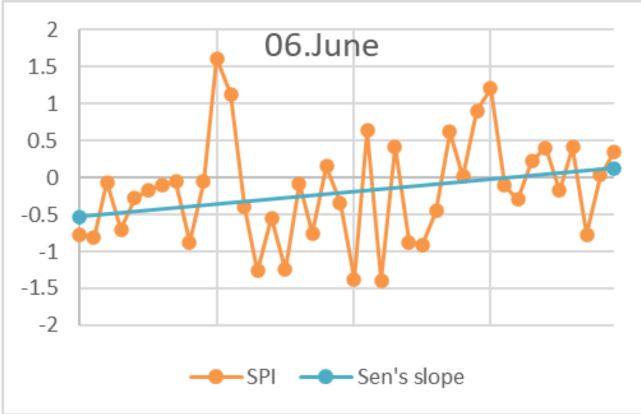

Figure 8. June Trend Graph

MK-z Tau value was calculated as 0.181 in June data. Since the calculated P value of 0.100 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.017.

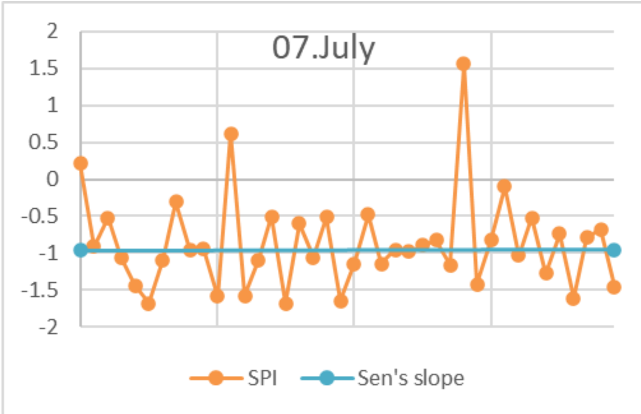

Figure 9. July Trend Graph

MK-z Tau value was calculated as 0.001 in July data. Since the calculated P value of 0.991 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.000.

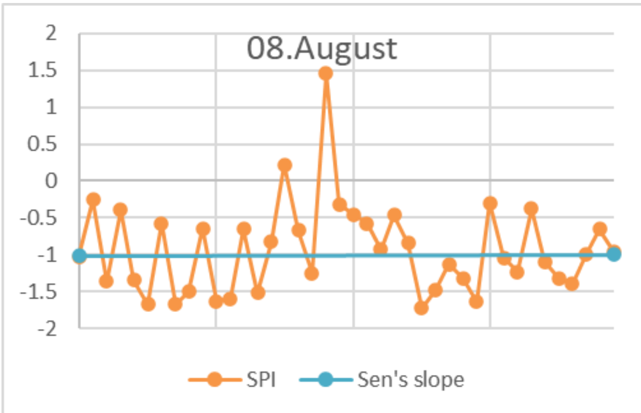

Figure 10. August Trend Graph

MK-z Tau value was calculated as 0.003 in August data. Since the calculated P value of 0.981 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.000.

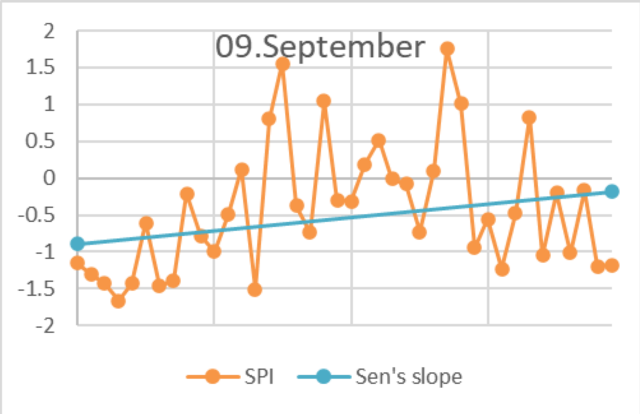

Figure 11. September Trend Graph

MK-z Tau value was calculated as 0.197 in September data. Since the calculated P value of 0.075 was lower than 10% significance level, the alternative hypothesis was accepted. Sen's Slope value was calculated as 0.018.

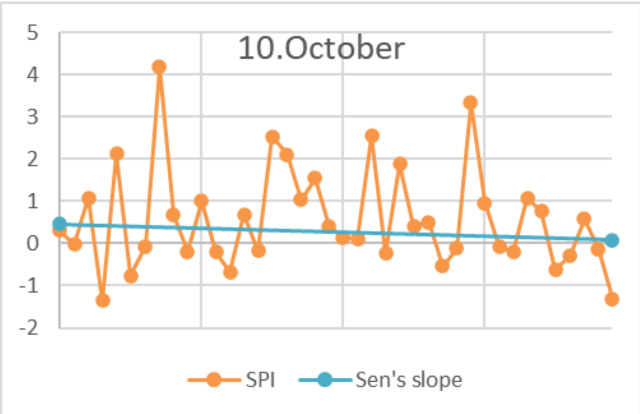

Figure 12. October Trend Graph

MK-z Tau value was calculated as -0.090 in October data. Since the calculated P value of 0.415 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as -0.010.

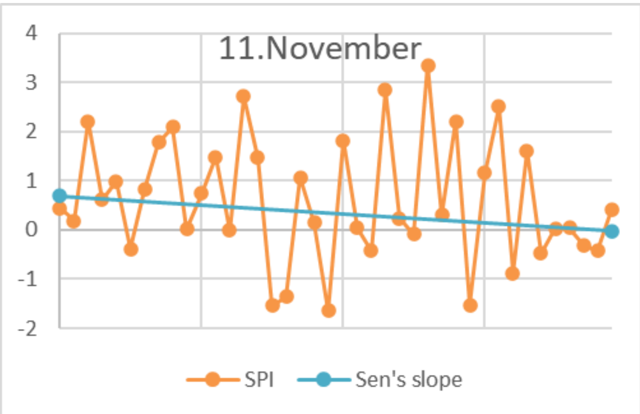

Figure 13. November Trend Graph

MK-z Tau value was calculated as -0.110 in November data. Since the calculated P value of 0.316 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as -0.018.

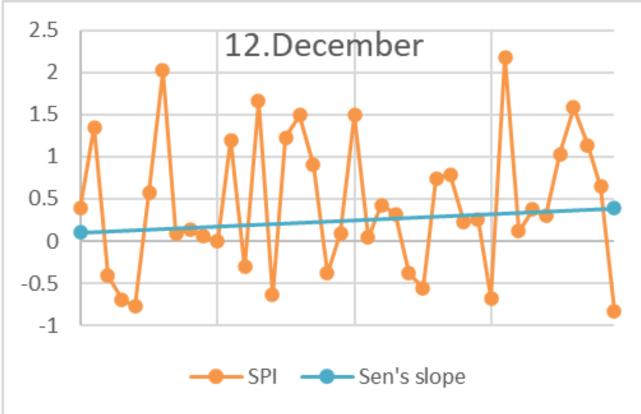

Figure 14. December Trend Graph

MK-z Tau value was calculated as 0.074 in December data. Since the calculated P value of 0.499 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.007.

4. Discussion and Conclusion

In this study, monthly precipitation data of Erbaa Plain in mm were used. SNHT was applied to monthly precipitation data and H_0 hypothesis was accepted since P = 0.466 value was higher than significance level 0.05 value. It was seen that the data were suitable for analysis.

The SPI values were analyzed with Mann-Kendall trend test, which is one of the non-parametric tests, as monthly. The analysis was made according to 10% significance level. According to the trend analysis, an increasing trend was determined in January and September. Although not statistically significant, an increasing trend was observed in March, May and June. A downward trend was observed in February, April, October and November.

The SPI values were analyzed with the Sen's Slope trend test, which is one of the non-parametric tests, for monthly with 10% significance level. According to the analysis results, Mann Kendall z values and Sen's Slope values show parallelism.

While there is generally increasing precipitation in the Erbaa Plain, droughts have been observed in recent years (2016-2020). It has been observed that the decreasing tends was in the autumn months, when the region receives the most precipitation. Also, an increasing trend was observed in the summer months, when the lowest drought was observed throughout the year. The plans should be made in order to reduce the damages that may occur due to the negative effects of climate change. Similar studies done for other regions of Turkey and hydrological and climatological elements. In this way, the formation and effects of climate changes can be observed on a wider scale and contribute to the planning to be made.

Author Contributions

1st Author: Conceptualization, Methodology, Software, Data Curation, Writing-Original Draft Preparation, Validation, Visualization
2nd Author: Visualization, Data Curation
3rd Author: Investigation, Reviewing and Editing

Statement of Conflicts of Interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics.

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Trend analysis of temperature and precipitation in Mediterranean region

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ABSTRACT

Hydrological parameters are heavily affected by climate changes and human activities. To confirm and take actions against such affects and changes caused by these affects trend analyzes must be performed. In this study, Linear Trend and Modified Mann-Kendall trend analyzes were performed using the annual average temperature data (̊C) and the annual total precipitation data (mm) between 1960-2020 of Burdur, Isparta, Kahramanmaraş, Muğla, Antalya, Mersin, Adana, Osmaniye, Antakya stations. The study concluded in increasing trends in temperature data (8 out of 9 stations) and no trend in precipitation data.

1. Introduction

Climate change has a long-term impact on the ecosystem, resulting in considerable changes in hydrometeorological parameters. A shift in the ecological equilibrium can have long-term consequences for the entire ecosystem. The most important of these indicators are the increases in the global average air temperature, the melting of the glaciers in the poles and inland areas, the rise in sea levels, the increase in the frequency and intensity of floods, droughts and precipitation (Büyükyıldız, 2004). For this reason, analysis of such parameters is important for detecting extremes. İçel (2009) analyzed temperature, precipitation, and extreme instances throughout the eastern Mediterranean coast and found an increasing trend in 11 stations, with the increase being more noticeable after 1992. Bahadır (2011) used the Growth Curve and ARIMA model to investigate temperature and precipitation trend changes in the Mediterranean Region and found that all stations showed an increase in temperature and a decrease in precipitation. İlker et. al. (2019), examined the spatial distribution of precipitation in the Mediterranean Region and created precipitation distribution maps with the help of Geographic Information Systems. In the control of these maps, the coefficient of determination and the root mean square error values were used (Bacanlı & Akşan (2019), found that all stations in the Mediterranean Region are between mild drought and normal. It was determined that Adana had the lowest percentage values in both wet and dry conditions compared to other stations. Durmuş et. al. (2021), Between 1980-2019 examined the changes in temperature and precipitation extremes. With the RH test, the breaking dates in homogeneity were determined. 17 temperature and 6 precipitation indices from the climate indices determined by WMO and CLIVAR were applied to the temperature and precipitation data. They found that while the maximum temperature average values increased by 2.4 °C in general, the minimum temperature average increased by 4 °C in the coastal areas.

Linear Trend and Modified Mann-Kendall trend analysis methods were used in this study to detect statistically significant trends, with 95 percent confidence intervals.

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2. Method

The Mediterranean Region includes three primary basins: the Eastern Mediterranean, Antalya, and Western Mediterranean basins. Agriculture and tourism are important industries in the region. The Mediterranean climate of the region has hot and dry summers and warm and heavy rains in the winter (Yılmaz et. al., 2021).

The spatial distribution of the stations used in the study is given in Figure 1. The numerical expressions in the figure show the global numbers of the stations. Statistical information of these stations and information about the recording period are given in Table 1.

Figure 1. Spatial distribution of stations used in the study

Table 1. Statistical information about temperature and precipitation data

No	Data	Period	Std. Dev.	Skew.	Kurt.
17238	Temp.	1960-2020	0.73	0.25	-0.32
Burdur	Pre.	1960-2020	85.30	0.02	-0.59
17240	Temp.	1960-2020	0.81	0.14	0.04
Isparta	Pre.	1960-2020	142.06	0.42	0.26
17255	Temp.	1960-2020	0.91	-0.17	-0.21
Kahramanmaraş	Pre.	1960-2016	171.22	0.69	0.25
17292	Temp.	1960-2020	0.58	0.02	-0.47
Muğla	Pre.	1960-2020	280.05	0.18	0.00
17302	Temp.	2001-2020	0.55	0.72	0.39
Antalya	Pre.	2006-2020	451.59	-0.30	-1.49
17340	Temp.	1960-2020	1.03	0.20	-0.93
Mersin	Pre.	1960-2020	182.46	0.53	0.03
17351	Temp.	1960-2020	0.57	0.28	0.54
Adana	Pre.	1960-2020	202.51	0.72	0.38
17355	Temp.	1986-2020	0.64	-0.23	0.01
Osmaniye	Pre.	1986-2020	168.43	0.35	0.18
17372	Temp.	1960-2020	0.64	-0.20	0.03
Antakya	Pre.	1960-2020	185.29	0.28	-0.22

* Temp. = Average temperature data (C), Pre. = Total precipitation data (mm)

Table 1, which contains statistical data on temperature and precipitation data, shows that the temperature data of the stations are distributed symmetrically, with the exception of one (17302/Antalya) station. When the kurtosis coefficients are examined in the same way, it is clear that all 9 stations are flatter (Platykurtic) than the normal distribution curve. Except for three (17255/Kahramanmaraş, 17340/Mersin, and 17351/Adana) stations, the stations are spread symmetrically for precipitation data. When the kurtosis coefficients are examined in the same way, it is clear that all 9 stations are flatter (Platykurtic) than the normal distribution curve (Yılmaz et. al., 2021).

2.1. Linear trend test

The linear trend test is a parametric test that is used to determine the existence or absence of a trend in a time series. It is based on the assumption that the data is normally distributed (Karabulut & Cosun 2009). The main application of this method is to identify the trend curve using a graph and a line fitted to the graph. (Yağbasan et al. 2020). The linear regression expression obtained for the linear trend is included in equation 1.

$$y_i = ax_i + b \qquad (1)$$

In Eq. 1. "a" represents slope and "b" represents the intersection point with the y axis (Demir, 2018). "a" and "b" values are calculated using Eq. 2. and 3.

$$a = \frac{\sum_{i=1}^{N} x_i y_i - N\bar{x}\bar{y}}{\sum_{i=1}^{N} x_i^2 - N\bar{x}^2} \qquad (2)$$

$$b = \bar{y} - a\bar{x} \qquad (3)$$

In Eq. 2. and 3. variables "N" represents the number of data in the series, "$\bar{x}$" represents the average of "x" variables, "$\bar{y}$" represents the average of "y" variables, "x_i" represents the "x" value in the "i-th" row, "y_i" represents the "y" value in the "i-th" row.

Trend existence is decided by applying "t" distribution and "t" test (Eq. 4.) (Student, 2018).

$$f(t) = \frac{\Gamma(\frac{v+1}{2})}{\sqrt{v\pi}\,\Gamma(\frac{v}{2})}\left(1 + \frac{t^2}{v}\right)^{-\frac{v+1}{2}} \qquad (4)$$

The calculated "t" value is compared with the "$t_{critical}$" value corresponding to the 95% significance level (Demir, 2018).

2.2. Modified mann-kendall test

Although the process is considered to be independent in the original Mann-Kendall test, a correlation is shown in most hydrological events, and the presence of positive autocorrelation increases the likelihood of identifying a significant trend (Yağbasan et al. 2020). Eqs. 5 and 6 are used to determine the variance value in order to eliminate this situation (Hamed & Rao 1998).

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} \sum_{i=1}^{n-1} (n-i)(n-i-2)\rho_s(i) \qquad (5)$$

$$V(S) = Var(S)\frac{n}{n_s^*} = \frac{n(n-1)(2n+5)}{18}\frac{n}{n_s^*} \qquad (6)$$

The remainder of the test is performed similarly to the original Mann-Kendall test After application calculated "Z" value compared with the "$Z_{critical}$" value to check statistically significant trend presence (Yılmaz et al., 2020).

3. Results

Linear and Modified Mann-Kendall trend analyses were used to investigate annual average temperature data (C) and annual total precipitation data (mm) for 9 stations in the Mediterranean Region from 1960 to 2020. Geographic Information System software is used to visualize the results (ArcGIS program-ArcMap sub package).

Results for temperature data are shown in Table 2.

Table 2. Trend test results for temperature data

No	Test	Critical Value	Result	Trend
17238 Burdur	LT	±1.67	3.77	Increasing
	MMK	±1.96	3.21	Increasing
17240 Isparta	LT	±1.67	3.23	Increasing
	MMK	±1.96	2.41	Increasing
17255 Kahramanmaraş	LT	±1.67	7.87	Increasing
	MMK	±1.96	6.11	Increasing
17292 Muğla	LT	±1.67	4.20	Increasing
	MMK	±1.96	3.06	Increasing
17302 Antalya	LT	-	-	-
	MMK	-	-	-
17340 Mersin	LT	±1.67	14.60	Increasing
	MMK	±1.96	8.00	Increasing
17351 Adana	LT	±1.67	3.92	Increasing
	MMK	±1.96	3.70	Increasing
17355 Osmaniye	LT	±1.69	2.97	Increasing
	MMK	±1.96	2.71	Increasing
17372 Antakya	LT	±1.67	3.55	Increasing
	MMK	±1.96	3.43	Increasing

-: Not enough data for trend analysis.
LT: Linear Trend Test
MMK: Modified Mann-Kendall Test

When the Table 2. examined, both test shows increasing trends in 8 stations which 2 of the stations shows extreme cases of increasing trends (17255/Kahramanmaraş, 17340/Mersin).

Maps of trend tests are shown in figures 2 and 3.

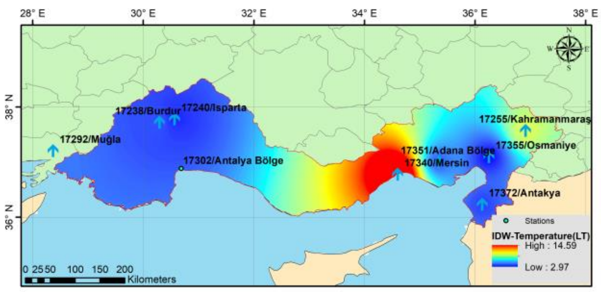

Figure 2. Linear Trend test results map for temperature data

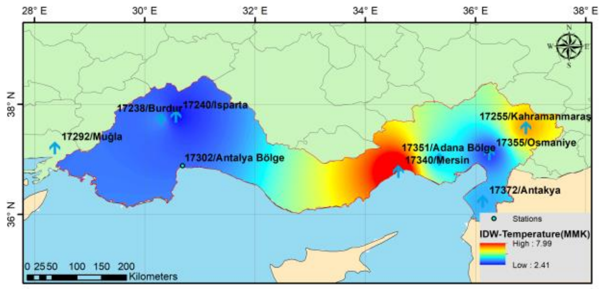

Figure 3. Modified Mann-Kendall trend test results map for temperature data

Results from trend tests for precipitation data are shown in Table 3.

Table 3. Trend test results for precipitation data

No	Test	Critical Value	Result	Trend
17238 Burdur	LT	±1.67	-0.04	No trend
	MMK	±1.96	0.13	No trend
17240 Isparta	LT	±1.67	-1.50	No trend
	MMK	±1.96	-0.78	No trend
17255 Kahramanmaraş	LT	±1.67	0.52	No trend
	MMK	±1.96	0.46	No trend
17292 Muğla	LT	±1.67	-1.13	No trend
	MMK	±1.96	-0.87	No trend
17302 Antalya	LT	-	-	-
	MMK	-	-	-
17340 Mersin	LT	±1.67	0.71	No trend
	MMK	±1.96	0.67	No trend
17351 Adana	LT	±1.67	-0.31	No trend
	MMK	±1.96	-0.21	No trend
17355 Osmaniye	LT	±1.69	-0.68	No trend
	MMK	±1.96	0.03	No trend
17372 Antakya	LT	±1.67	-0.76	No trend
	MMK	±1.96	-0.68	No trend

-: Not enough data for trend analysis.
LT: Linear Trend Test
MMK: Modified Mann-Kendall Test

When the Table 3. examined, no statistically significant trend detected.

As for the test results for individual stations:

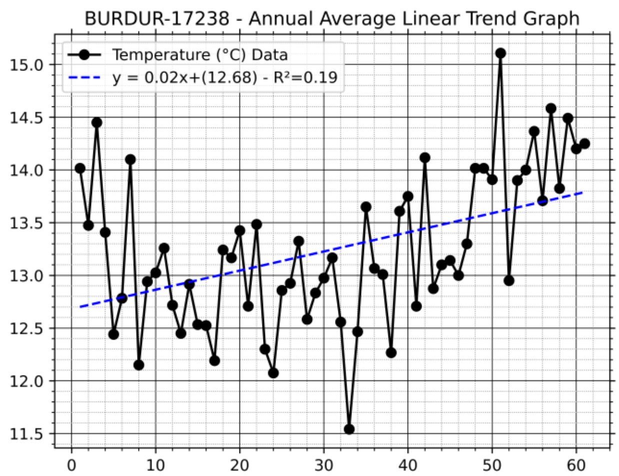

Figure 4. Linear Trend test graph for temperature data

As seen on Fig. 4 an increasing trend can be observed and observed trend is statistically significant for both Linear Trend test and Modified Mann-Kendall test (Table 2.).

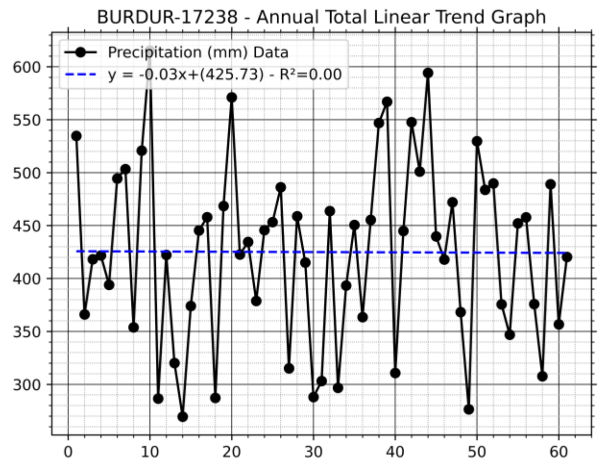

Figure 5. Linear Trend test graph for precipitation data

A decreasing trend can be observed (Fig. 5) in Burdur station but the observed trend is not statistically significant (Table 3.).

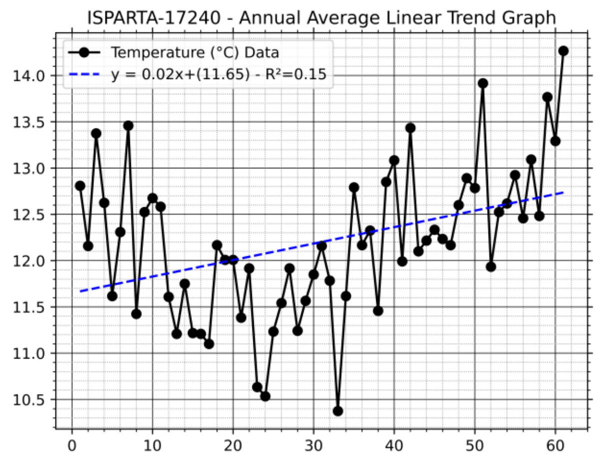

Figure 6. Linear Trend test graph for temperature data

Statistically significant increasing trend for both tests can be observed in Fig. 6 and Table 2.

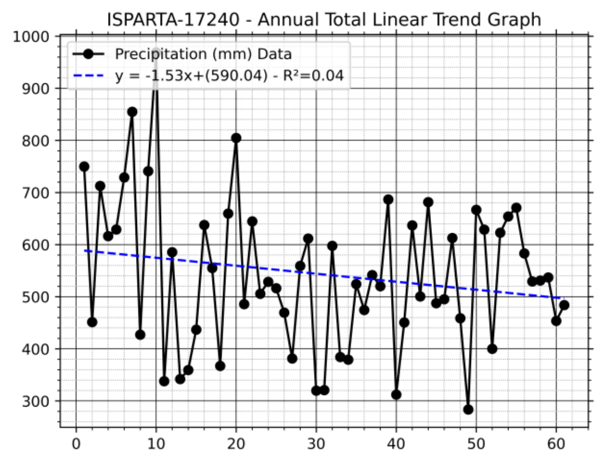

Figure 7. Linear Trend test graph for precipitation data

A decreasing trend can be observed for both tests (Fig 7 and Table 3.) but both results are below critical values.

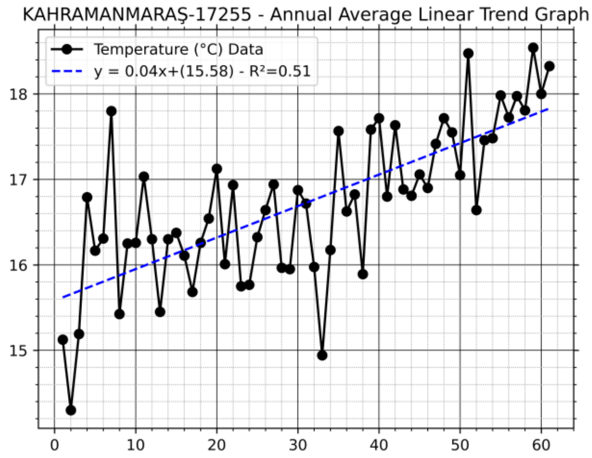

Figure 8. Linear Trend test graph for temperature data

In Kahramanmaraş station statistically significant increasing trend for both tests (Fig. 8 and Table 2.) has been observed.

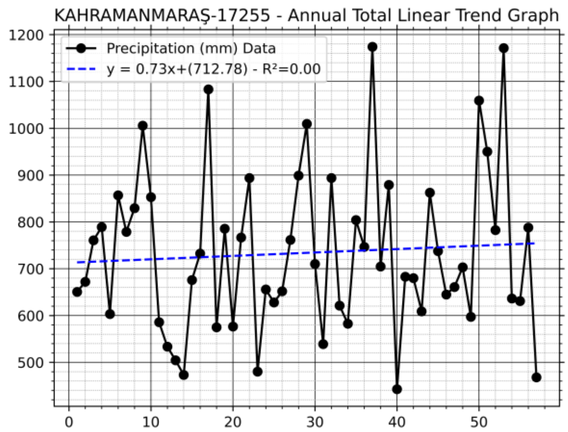

Figure 9. Linear Trend test graph for precipitation data

And a decreasing trend has been observed for precipitation data in Kahramanmaraş station but the observed trend is not statistically significant for both tests (Fig. 9 and Table 3.).

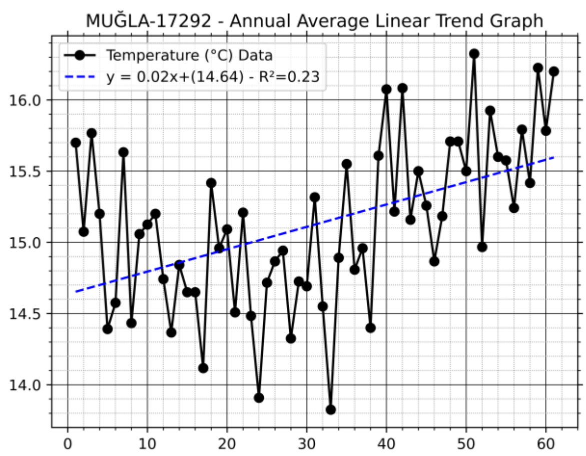

Figure 10. Linear Trend test graph for temperature data

Similarly, to the other stations an increasing trend for temperature data (Fig. 10, Table 2.) in Muğla station has been observed and the observed trend is statistically significant for both Linear Trend test and Modified Mann-Kendall test.

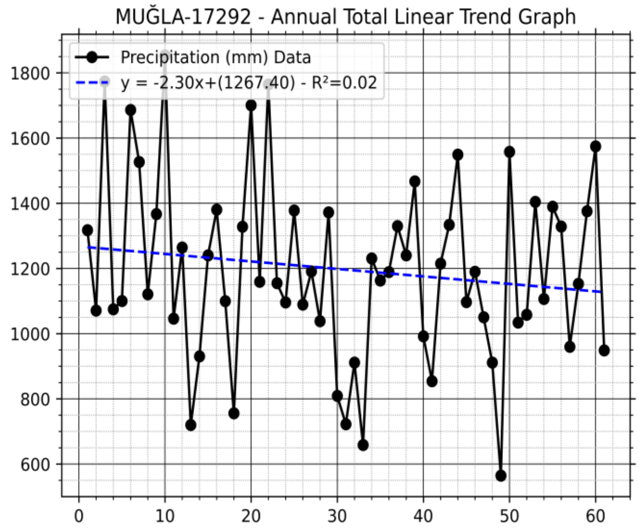

Figure 11. Linear Trend test graph for precipitation data

And a statistically unsignificant decreasing trend has been observed for the precipitation data (Fig. 11);

For Antalya station no trend test could have been applied due to insufficient data count for both temperature and precipitation data.

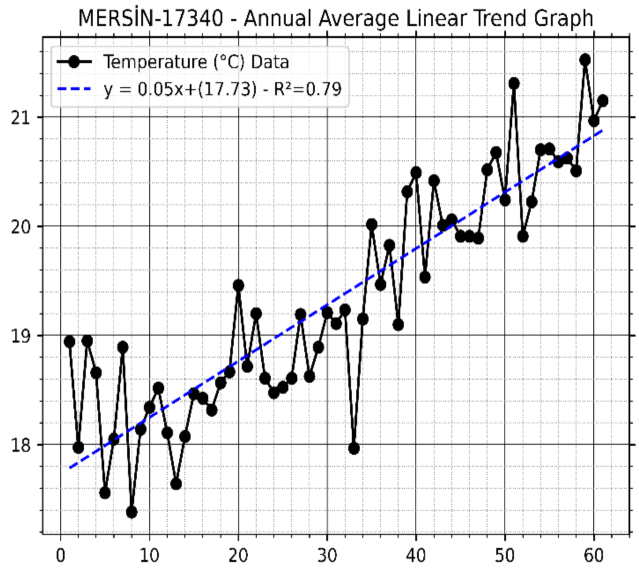

Figure 12. Linear Trend test graph for temperature data

As it is shown in Fig. 12 when the annual average temperature graph for Mersin station is examined a clear increase in temperature data over the years and statistically significant extreme case of increasing trend is observed for both tests (Table 2).

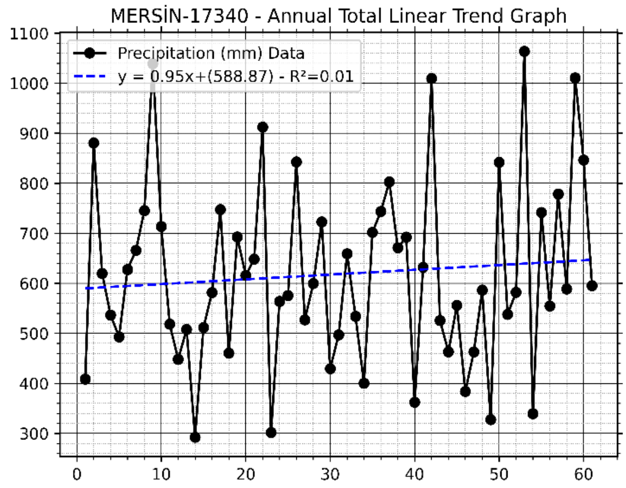

Figure 13. Linear Trend test graph for precipitation data

And an increasing trend can be observed for precipitation data (Fig. 13). But this observation is not statistically significant for both tests (Table 3).

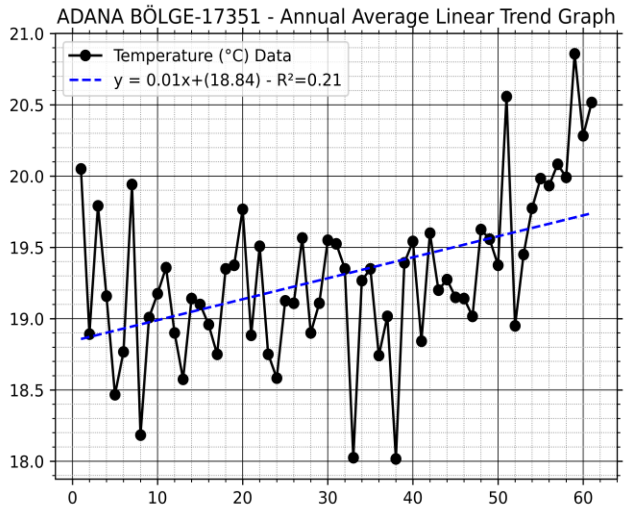

Figure 14. Linear Trend test graph for temperature data

A statistically significant trend has been observed for both Linear Trend test (Fig. 14) and Modified Mann-Kendall test (Table 2.) in Adana station for temperature data.

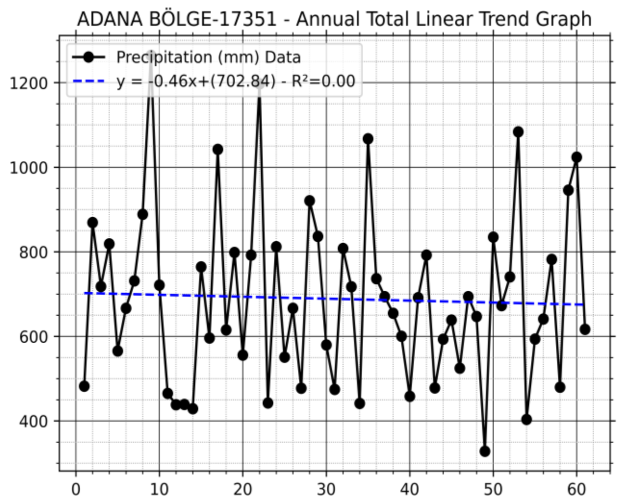

Figure 15. Linear Trend test graph for precipitation data

And a statistically unsignificant decreasing trend has been observed for the precipitation data in Adana station for both tests (Fig. 15, Table 3.).

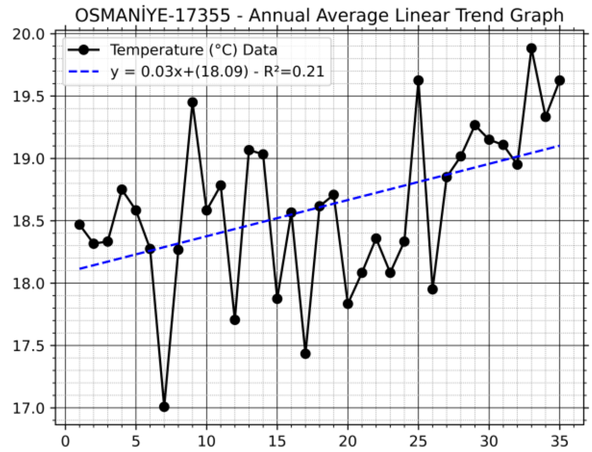

Figure 16. Linear Trend test graph for temperature data

A statistically significant trend for temperature data in Osmaniye station has been observed for both Linear Trend test (Fig. 16) and Modified Mann-Kendall test (Table 2.).

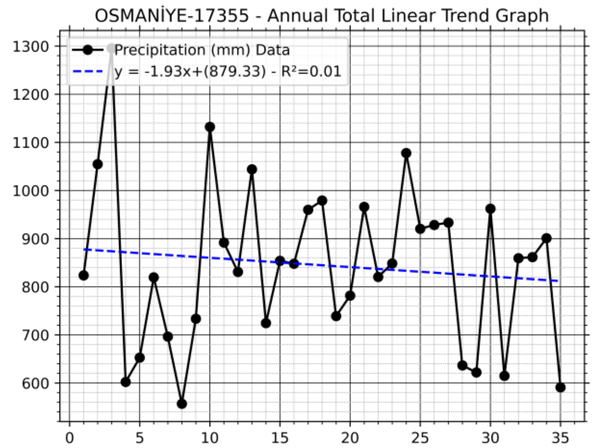

Figure 17. Linear Trend test graph for precipitation data

And a statistically unsignificant decreasing trend has been observed for both tests (Fig. 17, Table 3.) in Osmaniye station.

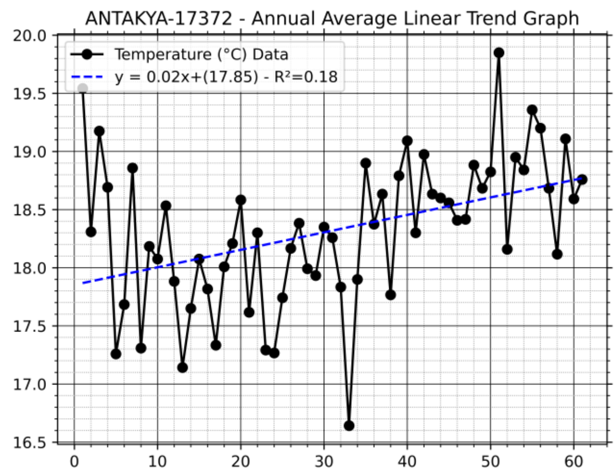

Figure 18. Linear Trend test graph for temperature data

In Antakya station statistically significant increasing trend has been observed for both tests (Fig. 18, Table 2.) for temperature data.

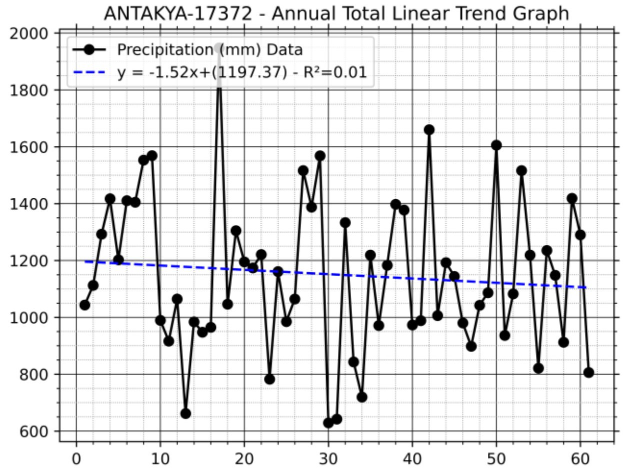

Figure 19. Linear Trend test graph for precipitation data

And statistically unsignificant decreasing trend has been observed for both tests (Fig. 19, Table 3.) in Antakya station for precipitation data.

4. Discussion

While temperature data usually gives a high coefficient of determination, the coefficient of determination values obtained from precipitation data are much lower. This conclusion indicates that the accuracy of linear trend analysis results decreases in data groups with high fluctuation. The increasing trends detected in the temperature data indicate that temperatures will increase in the near future.

5. Conclusion

When the temperature data from both tests is analyzed, both tests show an increasing trend in 8 stations, with two of these stations (17255/Kahramanmaraş, 17340/Mersin) having an extreme case of increasing trends. For both tests, no significant trend was detected in any of the stations when the same evaluation was applied to the precipitation results.

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Author Contributions

1st Author: Methodology, Software, Data, Writing-Original Draft Preparation, Visualization. 2nd, 3rd, and 5th Authors: Conceptualization, Reviewing and Editing.

4th Author: Providing data

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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WebGIS technology and architectures

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ABSTRACT

WebGIS allows everybody to reach geo-spatial data. It creates a rapid and advanced environment without place, time and the limitations of high processing power and high client computer. WebGIS, reshapes and makes use of all computer functions including gathering attribute data, storing, acquiring, analyzing and visualizing. WebGIS was employing the internet based maps and client-server architecture in order to provide these facilities to all. This architecture, however, has been switched to service oriented architecture, not being able to meet cope with, increasing data volume and number of access requests. Service oriented architecture, provides a service system, dynamic, elastic and re-contractible where meeting with different users. Also this improves the decision making progresses by spreading spatial information. This article analyzes WebGIS architectures and Technologies by emphasizing architecture.

1. Introduction

Desktop GIS software has enabled users to view spatial data and text-based information associated with that data in an appropriate format (Güleç Korumaz et al., 2011; Çoruhlu & Çelik, 2017; Çelik & Çoruhlu, 2021). As a result, spatial data has become easier to interpret and increasingly simple to understand. Unfortunately, everyone has access to desktop GIS and application development; This is not possible due to license fees, client-side system costs, and lack of time to use it efficiently (Çoruhlu et al., 2017). WebGIS is an inexpensive and easy way to disseminate geospatial data and processing tools. Many organizations, companies and research institutes are interested in distributing maps and rendering tools to users without the constraints of time and space (Alesheikh et al., 2002; Taşdemir et al., 2008; Yakar et al., 2010; Yakar & Doğan, 2016). These organizations have a lot of experience in software development. Different industries and sectors have had plenty of practice and experience. Numerous WebGIS solutions have emerged over the past two decades. The development of WebGIS software has reinvigorated the global software industry and system manufacturers and has set a challenge for the industry to come up with new standards and technologies. The full use of WebGIS, information technology and resources have a catalytic effect on the development of geographic information systems (Shouqun, 2015). To develop a successful WebGIS application, it is necessary to treat the application as a process rather than a step. The implementation should also fit the existing technology and system requirements (Alesheikh et al., 2002). This paper provides an overview of current Web GIS technologies and architectures.

2. WEBGIS technologies

The development and dissemination of the Internet provides two main possibilities that can greatly assist GIS users. First, the internet allows visual interaction with data. Clients can generate maps by installing a Web Server. As maps and related attribute data are published on the Internet, other users can see these updates and speed up their evaluation and decision-making processes. Second, geospatial data is widely accessible because the internet is available from almost anywhere. Users can work on GIS data from virtually anywhere and from any platform. Both of these features will reshape the way GIS users do their jobs in the very near future.

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The ease of access to data and the synthesis of its visual presentation make it easier for them to evaluate and perform geoscience analyzes (Gillavry, 2000).

WebGIS is not faultless. The primary issue is speed; GIS relies on extensive use of graphics. Connection speeds over the Internet can make heavy use of graphics unbearably slow for users. In the near future, special GIS programs such as "ArcView & ArcInfo" or "MapInfo" will not be the optimal solution due to the complexity, system requirements they require, license costs and rapid access to data in bulk. On the other hand, WebGIS does not need the same resources as these programs. For a large-scale GIS solution, WebGIS does not require client-side powerful computers, extensive training, and expensive site licenses (Strand, 1998).

2.1. Data formats

A decisive factor for using GIS on the Internet is which data type format (vector or raster) will be used to transfer the data to the client. In order for the client to view the data on their device, it is necessary to convert the map to raster or vector format by the server (Gillavry, 2000).

Then, the data converted to the desired format needs to be processed through tile (breakdown of all data into small data) and cache (map server caching the data that goes through the tile process) for speed of data access and fulfillment of requirements.

Raster data is the expression of spatial data as cellular frames. Represents a real state in cells (raster cell) with equally sized rows and columns. Each cell takes different color values depending on the geographic area and defines the geographic area it represents. The size of raster cells refers to the resolution of the dataset and the detail of the specified area. Satellite photos, scanned plans, orthophotos and any image work in raster format (KBS, 2021) (Figure 1).

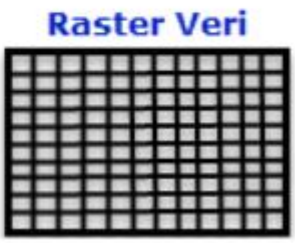

Figure 1. Raster data

Vector data is a data type that expresses spatial objects (point, line, closed area) on the earth and whose coordinate information is known. Complex shapes of space can be drawn using points, lines and closed areas. Each vector data type is held and organized in separate layers.

Point object is data represented by x, y coordinate pair (such as electric poles, wells).

The line object is represented by a set of x, y coordinates with a start and an end point (such as streams, roads).

The area object is represented by a sequence of x, y coordinates with the same start and end point. (such as building, parcel, vegetation)

In three-dimensional data sets, in addition to the x, y coordinate pair, the height information of the object or fracture is represented by the z coordinate (KBS, 2021) (Figure 2).

Figure 2. Vector data

The amount of vector data sent over the web can be three to four times less than the amount of raster data required for equivalent resolution, resulting in faster response time and productivity (Nayak, 2000). The choice of format (vector or raster) of the data to be transferred varies depending on the applications and existing infrastructures. Software products that optionally offer vector or raster data transfer may be advantageous (Leukert and Reinhardt, 2000).

Different consortia are developing different standards for data transfer over the internet. For example, the Open GIS consortium offers Geographical Markup Language (GML). GML will enable the transport and storage of geographic information in eXtensible Markup Language (XML). Geographic information includes both features and geometry of geographic data (OPENGIS, 2021). The W3C (The World Wide Web Consortium) offers Scalable Vector Graphics (SVG), a language that defines two-dimensional vector and mixed vector/raster graphics in XML (W3C, 2021).

2.2. The map types

We can collect the maps published on the Internet under three main headings.

Static (Stable) maps are maps that use known digital mapping techniques and bases.

Dynamic maps are maps that show traffic, migration, military advance, withdrawal and the related history, geography, state of engineering projects, two or more of these with special lines and arrows in a time unit.

Interactive (Interactive) maps are maps where users can make all kinds of interactions (add data, delete data, make measurements, broadcast, etc.) and the changes are published instantly. It is the most challenging map type in terms of WebGIS.

The Special Interest Group (SIG) within the OpenGIS Consortium is working on the problems of interactive maps in WebGIS. This group has recently developed a workflow model for interactive maps in a basic WebGIS (Figure 3).

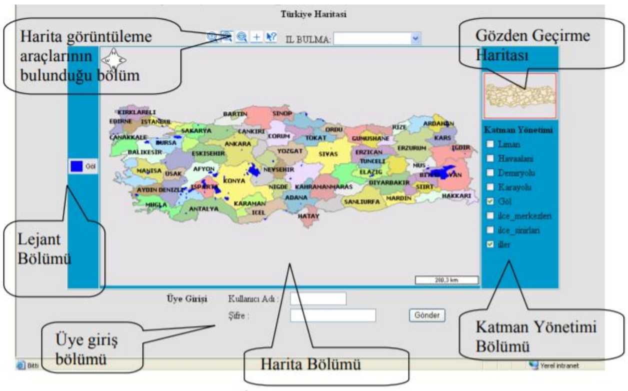

Figure 3. Interactive map home page (HARITA, 2021)

This model has four layers:

• The selection process retrieves data from a geospatial data source according to query constraints such as search area or thematic selections.

• The Image Element Generator process transforms selected geospatial data into a series of image elements. Adds styles such as symbols, line styles, fill styles to spatial properties, creates comments from alphanumeric attributes, sorts image elements in a specific order, and performs other graphical operations.

• Render takes display elements and creates a rendered map. Examples of generated maps are in-memory display lists, GIF files, or postscript files.

• View makes the created map visible to the user on a suitable display device.

Between these four layers, there are three different types of data:

Features and scopes from the selection process (e.g. scan data)

Display elements created from Display Element Builder

Render-generated images

2.3. WebGIS engine

The WebGIS engine is the hub of geographic information systems. A good map engine is essential to improve the responsiveness of WebGIS. Online maps communicate over the Internet, which is inevitably affected by the network transmission speed. Meanwhile, large amounts of data in GIS often cause display lag on the client page. Real-time data display is one of the most important factors in WebGIS (Zhihong, 2011).

2.4. Internet map server

Internet Map Server makes maps and spatial data accessible to end-users via a web browser. Publications can be provided within the institution/organization (intranet) as well as to the whole world (internet) (Alesheikh et al., 2002; Brandon, 1997).In order to prepare a map requested by the user in the map server, it is necessary to go through a number of stages. These stages from data source to map presentation are shown in Fig. 1 (ISO/TC211, 2000).

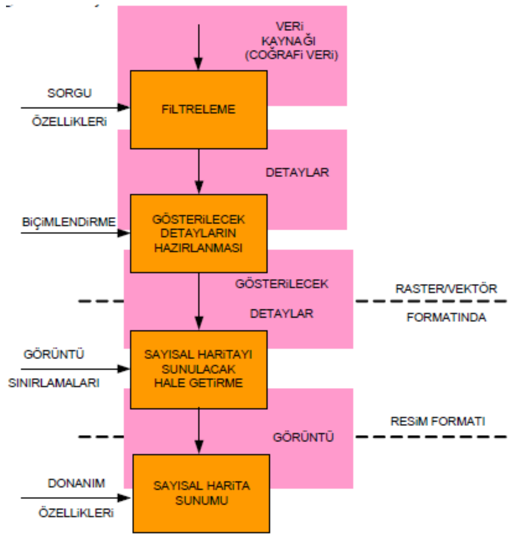

Figure 4. Process steps from the preparation of the image to its presentation (Erbaş & Taştan, N.D.)

3. WEBGIS architectures

We will examine two of the main architectures used to transmit geographic information to users via the Internet.

3.1. Server-client architecture

The main idea that creates the Client/Server models is to collect and combine various data and software on a computer accessible to users (Erbaş & Taştan, n.d.).

3.1.1. Server method

If users make requests from the server, the server evaluates these requests and transfers the desired image in HTML format. Internet-based GIS applications have spatial and attribute data on the server-side (Esri, 2021). The fact that the GIS application and spatial data are on the server side allows the applications to be easier (Erbaş & Taştan, n.d.).

3.1.2. Client method

In client applications, operations are performed on the client computer. The client must support GIS applications. The client makes a request from the server and displays the results on its own computer (Erbaş & Taştan, n.d.).

The biggest problem in server/client architecture is interoperability. Interoperability can be expressed as the ability of a unit to communicate with other units, transfer data and run applications without knowing the defining characteristics of other units. One of the most suitable methods to provide interoperability infrastructure is to use Service Oriented Architecture (SOA) based Web service applications (Gümüşay, 2019).

3.2. Service oriented architecture

Service-Oriented Architecture (SOA) provides the opportunity to create a distributed, dynamic, flexible, and reconfigurable service system that will meet the needs of different users. DEM basically consists of services that communicate with each other through defined interfaces. SYM creates an infrastructure that allows the data and functions of the service to be used by other services or users. With the DEM approach, it is possible to create flexible, easy-to-maintain, and consistent systems that can easily adapt to changing needs and technologies. The basic principles of DEM, which is an important guide in the design and development of service and service interfaces, are as follows (Gümüşay, 2019).

3.2.1. Loose commitment

Like loose fit, interoperability is important in realizing successful DEM. Interoperability removes the impact of technological features and limitations that would prevent or limit interoperability in DEM. Interoperability allows services and users to exchange information and work together using different technologies. The basic principle of SYM is that services and users work together regardless of the platform they are developed on. Like this; A service developed using Java and Oracle database on the Linux operating system can also be easily used by a client developed using Visual C++ on the Windows platform. Messaging plays an important role in supporting interoperability and loose cohesion through interfaces developed in accordance with certain standards (Gümüşay, 2019).

3.2.2. Reusability

Reusability optimizes design and development processes, minimizing new system development costs. The principle of reusability is to design and develop applications with an emphasis on reducing costs. It is possible to reuse a service designed and developed to support loose compliance and interoperability principles. So much so that all kinds of users can benefit from a common service that meets their needs without needing a specific service (Gümüşay, 2019).

3.2.3. Availability

Usability supports reusability and requires services to be published in an easy-to-find way. In order for a service to be preferred by different users, the service must exist. No matter how extensive a service is, it will have no effect if the service cannot be found for later use. The way to find a service is to use the catalog service. The catalog service stores information about services and provides facilities to find this information. Thus, those who design and implement new systems can find existing services that they can use through catalog services (Gümüşay, 2019).

3.2.4. SYM Find-Connect-Run

In this model, service providers register their services in service registers. The service records made are used by the clients to find the services that match the features they want. If the service requested by the client is available in the service records, the registrar sends the address and information of the service to the client (Gümüşay, 2019).

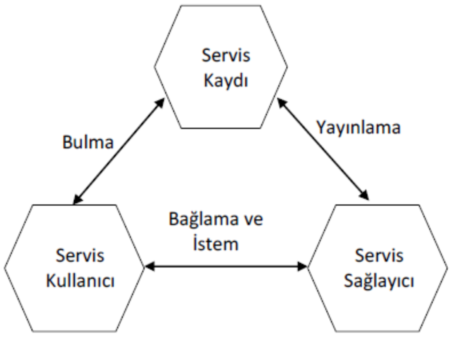

Figure 5. DEM find-connect-run (Gümüşay, 2019)

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The contributions of the Authors of this article is equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

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Research and publication ethics were complied with in the study.

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Determination of unsuitability points on the route of Van Gölü-Kapıköy railway line by using GIS and AHP method

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ABSTRACT

It is seen that there is a parallelism between the economic power of the countries and the development of the logistics sector of their sustainable competition. According to the free market economy in the Keynesian economic system, the logistics sector has an important function. With the globalization of the world, the logistics sector gains importance and this makes railway logistics gain importance. The development of railways allows the development of the economy. Since it positively affects the cost-benefit analysis of public institutions and organizations and the private sector, the railway route should be chosen in the most appropriate way. In the determination of the route Geographic Information System (GIS) applications are used with the developing technology in recent years. Geographic Information Systems applications, on the other hand, play a major role in collecting data analytically, obtaining results and using the results thanks to computer technologies and software systems. The Analytical Hierarchy Process (AHP) method, which is used together with Geographic Information System (GIS) applications, makes it possible to provide the most appropriate and maximum benefit in line with certain parameters by comparing the alternatives in the decision-making process in the most appropriate way. These parameters considered include slope, aspect, stream, building, small water flow and transportation. Taking these parameters into account, the conditions affecting the railway line were evaluated using the AHP method.

1. Introduction

The importance of logistics has increased in line with the increasing need for raw materials and market needs due to the increasing industrialization activities with the industrial revolution. This has led to the transportation sector gaining importance. In transportation, it has led to the search for alternative ways to ensure that heavy, large-volume loads reach the maximum benefit with the least cost, in accordance with the reliability, economy and efficiency standards. The most suitable of these roads is undoubtedly the railways. The logistics sector has gained momentum with the railways. With the increase in the importance of the railway in logistics, priority was given to railway investments, causing it to gain importance at the national and international level. Railways used in public institutions and organizations and in the private sector maintain their place in the globalizing world and are developing day by day. (Doğan & Ateş, 2019; Erkaya, 2019)

In the study, Analytical Hierarchy Process (AHP) and GIS methods were used to determine the points that are not suitable for the current railway in terms of topographic and settlement angles. Kiema, Dang'ana and Karanja et al. studies in the Kenya-Sudan GIS-based suitability for the rail route selection and analytical hierarchy process (AHP) model of success largely depends on several criteria determined in accordance with points allocated to the integrity of elections, this bolstered with CBS has said that it will provide good results. Here, too, it conveniently shows that GIS is an effective and efficient means of railway transportation. He also stated that it is up to engineers, consultants and environmental experts to implement the studies well (Kiema et al., 2007).

Erkaya stated in her study that other types of transportation are not ideal and economical like railway transportation. In particular, he stated that rail transportation is the best answer to the expected conditions from other transport systems. Mesala has stated that the railway is the most suitable for freight

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logistics. However, he pointed out to us that the railway planning stage is facing difficulties, that in order to eliminate these difficulties and to use this transportation in the most favourable way, the railway line should be modelled with the most appropriate model (Erkaya, 2019).

Panchal & Debbarma, in his work, the parameters of the main effects of topography construction on the railway route located in the rear Shiwalik were taken into account and the acceleration of the current railway route was discussed. Using the AHP direction, a more appropriate route analysis was determined and the criterion that the previous railway plan was not taken into account was determined, and it was determined that the factors in the construction of the topography should be taken into account for a plan. (Panchal & Debbarma, 2011).

Various parameters affecting the feasibility of the railway route will be planned to be transformed in layers using the Geographical information system (GIS). The slope layer can be run from the digital elevation model (DEM) of the workspace. Maps are scanned and imported in ArcGIS 10. Maps will be digitized using linear and polygonal tools by selecting georeferenced. Then the Digitized data will be converted to raster format. The weight value calculated by applying the Analytical Hierarchy Process (AHP) method to all layers prepared in the geographic information system (GIS) environment will be obtained and the consistency ratio will be determined. The layers prepared in the geographic information system (GIS) will be processed with weighted overlay. As the layers are superimposed, maps will be created with the combination of the various layers. The combination of the weight of the layers is called the Feasibility Index. The output map, which is the output of the layer combination, will be based on the feasibility index and the cumulative effect of the factors considered will be shown. Responsibility for the implementation of the principles of interoperability determined by the Ministry for geographic data, geographic data set and geographic data services in order to ensure interoperability and compatibility between the geographic data themes they are responsible for belongs to the relevant institutions and organizations. (Tri Dev et al., 2017)

Geographical information system (GIS) provides maps and analysis opportunities in many sectors such as logistics, distribution and urban planning. Supporting the logistics activities that form the link between the members of the supply chain with Geographical information system (GIS) applications; It provides benefits such as reducing costs, making communication and operations more effective. In addition, logistics enterprises prefer Geographical information system (GIS) applications in their activities, providing competitive advantage; can increase their market share. By using GIS technology in determining the routes in freight transportation, In addition to this; As a result of the logistics enterprises investing in Geographic Information System (GIS) technologies, the possible benefits of these investments to their activities are quickly seen (Çekerol & Nalçakan, 2011).

In our country, the railway route was determined by considering the topographic structure, special location, and the location of the mountains in terms of regions, and thanks to this route, it was used on a national and international scale. The lines used in railway logistics make great contributions to the economy of the country and the region where it passes. Thanks to the railway lines, the country gains economic vitality, a sustainable competitive environment is created and scientific technological innovations are made in the country thanks to the advantages brought by competition (Kalkan & Kalkan, 2016)

2. Method

This section provides information about the study area, the data sets used, and the methods used.

2.1. Study area

In the east of our country, the importance of railways is increasing due to the mountainous topographic structure and being far from the sea. The existing Van Lake- Kapıköy railway route, which is used in freight transportation, is one of our most important lines used in transit trade with the neighbouring country Iran figure 1.

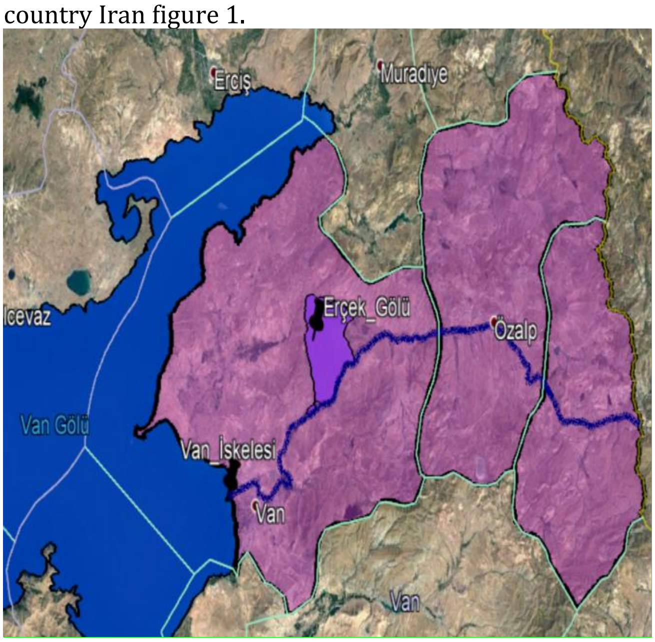

Figure1. Study area of the examined railway line

The Van Lake - Kapıköy line, which is examined in our country, plays an important role in freight transportation to Iran and other countries. The logistics we have chosen provides the development of combined transportation in the centre located on the railway line. The developing economy with the contributions of the railway line increases the economic welfare in the country or in the region. In railway logistics, it maintains its importance in logistics due to the transportation of heavy and costly loads with the most convenient and minimum cost. (Doğan & Ateş, 2019)

With the use of Geographic Information Systems (GIS) in determining the unsuitability points for the current route shown in figure 2 the analysis of analogue maps has started to be used in necessary studies and feasibility studies using modern computer technologies instead of expensive, inefficient and old techniques. Geographical Information Systems (GIS) usage areas provide great convenience to people working in this field with its use in countries and regional areas around the world. The applications used together with these facilities should be used in an efficient, economical and effective manner in accordance with their purposes. In addition, route planning is a very difficult task in mountainous regions. Route planning is more difficult on the Van Lake- Kapıköy line. Because of the topographical structure of the Van Lake-Kapıköy line, unsuitability points should be determined by considering the risks for logistics transportation such as large rocks falling from the mountains, sloping land, view and stream. (Weiwe & Ye, 2019)

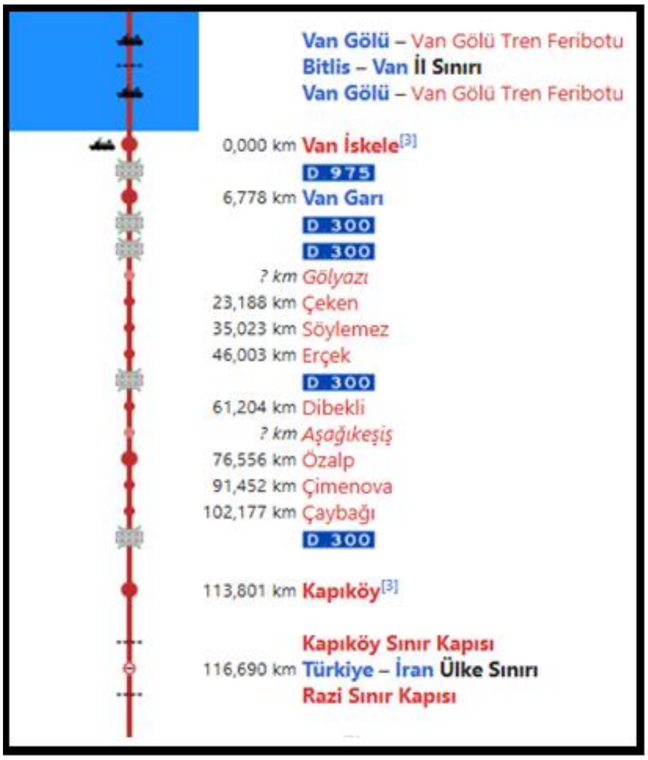

Figure 2. Van Lake–Kapıköy railway village and district names where the route passes

2.2. Data

In order to realize a certain purpose, the parameters suitable for this purpose must be determined in the most rational way. For these reasons, we should choose parameters suitable for our purpose. Necessary studies should be carried out for the modernization of the railway line between Lake Van-Kapıköy. For this purpose, the parameters affecting this line were evaluated first.

In addition, various parameters that affect the alignment of the railway route used for railway logistics will be considered. These analysed parameters are an important factor in determining the unsuitable areas of the logistics route.

The investigated criteria are:

- Slope
- Aspect
- Stream Line
- Transport
- Rivers and water bodies
- Building

The above factors should be investigated and the decisions should be processed and analysed in the most rational way and in the most appropriate GIS-based programs.

2.3. Analytical hierarchy process (AHP)

Analytical Hierarchy Process (AHP) method used in this study. Each criterion was digitized and represented by a layer in the GIS environment. These factors and their sub-criteria are weighted according to the analytic hierarchy process and reclassified layers were applied to obtain the map showing the unsuitability points in region. In practice, the Analytical hierarchy process (AHP) was used to determine the relative importance of each criterion.

If we start with the definition of the Analytical Hierarchy Process (AHP), the Analytical Hierarchy Process is the decision-making process that creates criteria and alternatives and evaluates them in the most appropriate way to achieve the determined purpose. The Analytical Hierarchy process (AHP) includes both rating and comparison methods. Rationality requires developing a reliable hierarchical structure or feedback network that includes necessary and efficient alternative criteria to make the most appropriate choice. Instead of evaluating the necessary norms, alternatives are sometimes compared. Within the framework of these comparisons, the most appropriate consistency range is determined. The purpose of this comparison is to determine the basic criteria and alternatives and to define them in an optimal hierarchical order, to reach the conclusion by comparing the criteria and alternatives with each other. The analytical hierarchy process (AHP) is based on three basic principles. These are the establishment of hierarchies, determination of superiorities, and logical and numerical consistency. Purpose, criteria and alternatives are determined by creating hierarchical stages. (Fan & Qian Xue, 2018; Özdemir et al., 2020)

These stages are linked to all existing parts. It is easy to see how a change in any of them will affect the stage. In decision making, a lot of data is brought together in this way and comparisons can be made between parts that look different. During this phase, the most appropriate choice is made to apply certain criteria. These operations must be logically and numerically consistent. With the help of a nominal clock, the elements that make up the hierarchy are compared in pairs. Comparisons are calculated to create a comparison matrix. Between the mathematical operations and the various elements of the hierarchy is the eigenvector of the matrix. The eigenvector is used to evaluate whether the consistency ratio of the comparative matrix is reasonable. If we consider the analytical hierarchy process for railway logistics, it is a multi-criteria decision-making technique used to find the relative importance of the line's criteria. The criteria to be examined in the unsuitability points map to be created; slope, aspect, stream, building, rivers/water bodies and transportation map (Fan & Qian Xue, 2018).

Table 1. Reference scale table to be used in the AHP method

Scale	Degree of preference	Explanation
1	equal	The two activities contribute to an equal purpose.
3	Medium	Experience and judgment somewhat favor an above-average efficacy.
5	Strong	Experience and judgment Strongly favor an activity over value.
7	Very strong	Experience and judgment very strongly favor an activity over value.
9	Extreme	An event affects the target to the greatest possible degree.
2,4,6,8	Intermediate value	It is used to present the compromise between 1,3,5,7,9 values.
Opposite	Mutual Opposites	It is used for inverse comparison.

A value from 1 to 9 is used to calculate the relative importance of these criteria. Table 1 shows the recommended reference scale. The preference criteria given in Table 1 are used to compare various parameters.

AHP is evaluated by comparing the consistency ratio calculation with the number of factors present and the baseline coefficient. Explained with the following items;

- After obtaining the pairwise comparison matrix, normalization is performed.
- After normalization, the priority vector is obtained. A consistency test is performed to see if the pairwise comparisons are consistent.
- CR, CI and RI values are used to perform consistency tests.
- RI value changes the number of criteria.

Table 2. Table of numbers of criteria to be used for consistency

Number of Criteria	Random Index Values (RI)
3	0,58
4	0,90
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,49
11	1,51
12	1,53
13	1,56
14	1,57
15	1,59

The recommended number of criteria is shown in Table 2. The random index values given in Table 2 are used to compare various parameters.

2.3.1. Process steps of AHP method

- The first step is to define the problem,

It is to determine what we will select and sort for the railway line that is handled with this process step figure 3.

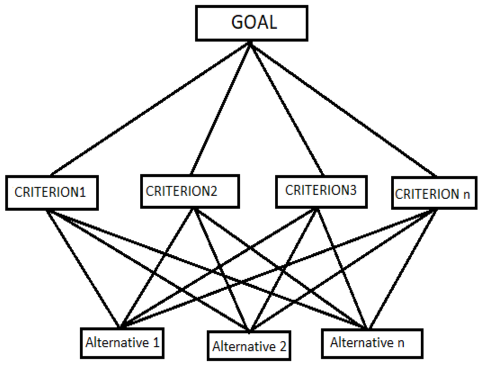

Figure 3. AHP schema

- In the second processing step, the comparison matrix is created,

The comparison matrix is an n*n square matrix. The matrix components on the diagonal of this matrix take values of 1.

Table 3. Alternatives table display

ALTERNATIVES Comparison Matrix by J Criteria				
	A1	A2	...	Am
A1	a11	a12	...	a1m
A2	a21	a22	...	a2m
...	...	...	...	...
Am	Am1	Am2	...	amm

Here;
m: number of alternatives
ai: i alternative i=1,2,3,...,m
aik: importance degree according to i alternative aik=1/aik and aii=1

$$\boldsymbol{A} = \begin{bmatrix} a11 & a12 & \dots & a1n \\ a21 & a22 & \dots & an2 \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ an1 & an2 & \dots & anm \end{bmatrix} \quad (1)$$

- The third process step is to obtain the normalization value, Normalization formula;

$$\mathrm{bij} = \frac{\mathrm{aij}}{\sum_{i=1}^{n} \mathrm{aij}} \quad (2)$$

- The fourth operation is to obtain the priority vector, After the Normalization Operation, the normalized matrix is obtained.

$$C = \begin{bmatrix} c11 & c12 & \dots & c1n \\ c21 & c22 & \dots & c2n \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ cn1 & cn2 & \dots & cnn \end{bmatrix} \quad (3)$$

- The fifth process step is to perform consistency tests,The priority vector is obtained as follows.

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \quad (4)$$

- The sixth process step is the selection or sorting process.

Consistency Tests
In order to perform consistency tests;

- Concordance index (CI)
- Random Index (RI)
- Concordance rate (CR)
- Values are needed.

$$CR = \frac{\text{CI}}{\text{RI}} \quad (5)$$

It is calculated with the formula.

If the calculated CR value is less than 0.10, it indicates that the comparisons made by the decision maker are consistent. A CR value greater than 0.10 indicates either a computational error or inconsistency in the decision-maker's responses to the comparison matrix. The fit index formula is as follows.

$$CI = \frac{\lambda\text{max}-n}{n-1} \quad (6)$$

n: Number of Observations
λmax: Basic Eigenvalue

Where; the λ value is calculated as follows;

First of all, D column vector is obtained from matrix multiplication of A comparison matrix and W priority vector.

$$D = \begin{bmatrix} a11 & a12 & \dots & a1n \\ a21 & a22 & \dots & a2n \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ an1 & an2 & \dots & ann \end{bmatrix} \times \begin{bmatrix} w1 \\ w2 \\ . \\ . \\ . \\ wn \end{bmatrix} \quad (7)$$

Then, by dividing the reciprocal elements in the column vector [D] and the column vector [CW], the matrix [E] of the base values of each evaluation factor is obtained.

$$Ei = \frac{Di}{Wi} \quad (8)$$

$$\lambda = \frac{\sum_{i=1}^{n} Ei}{n} \quad (9)$$

Finally, the basic value coefficient is calculated by taking the arithmetic average of the items in the [E] matrix. We will obtain land with the help of these formulas.

3. Results

3.1. AHP results

First, the criteria covering the study area were determined. The criteria handled by this process step is to determine that we will select and sort for the railway line. Selected criteria; earthquake, flood, rockfall, avalanche and landslide factors. Comparison matrix is made between these selected criteria and since there are six criteria, a 6*6 square matrix is obtained. Matrix components on the diagonal of this matrix take the values of 1, since no criteria are superior to itself.

After the comparison matrix obtained in figure (3), the normalization value in figure (4) is obtained as the third processing step. In order to obtain this normalization table, Total (t) and Criterion weight (c) are calculated in the comparison method in the first tableThe fifth processing step is calculated with the formula CR=CI/RI in figure (6) to perform the consistency test.

With the help of the values in the Normalization table in figure (4), the priority vector and normalization process are performed and the consistency process will be performed in the province.

It is first calculated with the formula $CI = \frac{\lambda\text{max}-n}{n-1}$.

"n" (number of observations) is subtracted from the value of λ_{max} (6,428656393) obtained in Table (3.2.4.).

λ_{max} -n=6,428656393-6 = 0,428656393 ………..1.

n-1=6-1=5 ……………………..2.

$CI = \frac{\lambda\text{max}-n}{n-1} = \frac{0,428656393}{5} = 0,085731279$

By using the Table of Criteria Numbers to be Used for Consistency in Table (2.1.2.), the "RI" (Random Index Values) value is selected in accordance with our criterion number value. Since the number of criteria is 5, Random Index Values (RI) are taken as 1.252 in Table (2.1.2.).

$CR = \frac{\text{CI}}{\text{RI}} = \frac{0.085731279}{1.252} = 0.068475462$…………..result

By using the Analytical Hierarchy Analysis method, which is a multi-criteria decision-making technique used to find the relative importance of the criteria, it is assigned to criteria such as earthquake, flood, rockfall, avalanche and landslide, and the final weight is found by relative comparison. The solution is then checked for consistency. If found consistent, the calculated weights can be assigned to each criterion and sub-criteria.

Consistency ratio (CR) consistency of solution;

✓ The parameters are considered appropriate if the CR value is < 10%. It is suitable and usable for analysis.

✓ If the CR value is > 10%, the parameters are not suitable.

Therefore, preferences are reviewed to obtain a consistency result. The CR (Consistency Ratio) value was found to be 0.068475462 as a result of the transactions. The CR value is 0.07 rounded off. Since the Consistency Ratio is 07% < 10%, the result obtained according to the consistency of the solution; The parameters selected and considered suitable for analysis can be used.

Table 4. Criteria of parameter

	S	A	SL	B	WB	T	W (c)
S	1	7	5	4	9	9	0,50
A	1/7	1	2	2	3	5	0,16
SL	1/5	1/2	1	3	5	7	0,18
B	1/4	1/2	1/3	1	2	3	0,09
WB	1/9	1/3	1/5	1/2	1	2	0,05
T	1/9	1/5	1/7	1/3	0,5	1	0,03

S: Slope, A: Aspect, SL: Stream Line, B: Buildings, WB: Water Bodies, T: Transport

3.2. Standardization of sub-criteria layers for unsuitability points

Many criteria are not suitable for this line on the route that the railway has passed. The influence of each factor on its alignment is outlined below "Fig. 4".

3.2.1. Slope

The slope factor is the ratio of the horizontal distance between two points to the difference in elevation. The difference in height between two points at a certain horizontal distance is specified as the slope. The fact that the existing line in the study area is located in a mountainous region necessitates the selection of the lowest slope and the most appropriate slope of the line selected for the route. The slope layer can be run from the digital elevation model (DEM) of the workspace. slope factor; It is classified into 7 groups as flat, almost flat, slightly sloping, moderately sloping, steeply sloping, very steeply sloping, steep sloping, very steep sloping.

The slope of the land is considered very critical on the railway route because it directly affects the railway route. The proposed railway line should not pass through areas with high slopes. The high slope in railway transportation increases energy consumption, reduces speed, and makes it difficult for wagons to carry freight. If the slope in the study area is more than 25 degrees, it increases the cost of the project as the probability of landslides close to the railway track increases. The slope layer of the study area is shown in figure 4.

Table 5. Classification of slope factor

Categories	Range	Rating
Flat	0-5	1
Slightly Sloping	5,1-10	2
Medium Slope	10,1-15	3
Steep Slope	15,1-20	4
Very Steep Slope	20,1-25	5
Steep Slope	25,1-30	7
Very Steep Slope	30,1-76,4	9

3.2.2. Aspect

In mountainous areas, the direction of view of a slope or a surface is a situation that determines its position against the sun's rays, south or north, and determines the resulting natural conditions. The aspect factor is very important for the railway passing in mountainous regions. Because the snow masses formed in snowfall turn into avalanches and the sun rays coming from the view cause an avalanche, which is a natural disaster, which causes an accident and leads to the closure of the line figure 4.

Table 6. Classification of aspect factor

Categories	Range	Rating
Flat	(-1)	0
North	(0°- 22.5°)-(337.5°- 360°)	9
Northeast	(22.5° - 67.5°)	7
East	(67.5° - 112.5°)	5
South East	(112.5° - 157.5°)	2
South	(157.5° - 202.5°)	0
South West	(202.5° - 247.5°)	1
West	(247.5° - 292.5°)	3
Northwest	(292.5° - 337.5°)	4

3.2.3. Stream and accumulation line

In some of the waters flowing on the soil surface, the flow is such that it covers the entire surface like a cover. It covers the incoming waters in small lines. Streams are formed when water collects and flows along a certain line. Being in small lines shows the branching of the waters and the presence of small water flows on the railway line causes deformation on the rails at the bottom figure 4.

Table 7. Classification of stream water flow factor,

Range	Rating
1-4	0
5-6	1
7-9	5
10-11	7
+11	9

3.2.4. Transport

The existing rail line should be close to major cities or villages due to accessibility concerns. Thus, it reduces the cost of the railway. The transportation of the study area is an important factor affecting the route planning process. If the railway facility is too far from important places, it will be difficult to use "Fig. 4".

Table 8. Classification of transport factor

Range	Rating
0-100	0
101-200	1
201-300	3
301-400	5
401-500	7

3.2.5. River and other water bodies

The river and water bodies flows continuously or at regular intervals in the direction of the slope of the earth in a certain place on the earth and underground. Rivers appear as the most important external factor in shaping the geography we live in, beyond just meeting the needs of people for agriculture and energy.

Streams shape the earth by erosion and deposition. Due to this important feature, it plays an important role in the places where the railway passes. This factor causes landslides and floods in a negative role in the railway. This can lead to major disruptions and accidents in rail transport figure 4.

Table 9. Classification of water bodies factor

Range	Rating
....	7
...	9

3.2.6. Building

An important part of his research in railway transport is not only to ensure the safety of passengers or the convenience of freight transport, but also to protect the people living in the railway vicinity from disturbing and damaging vibrations in buildings and to reduce these vibrations "Fig. 4".

Table 10. Classification of Building Factor

Range	Rating
	0
	5
	9

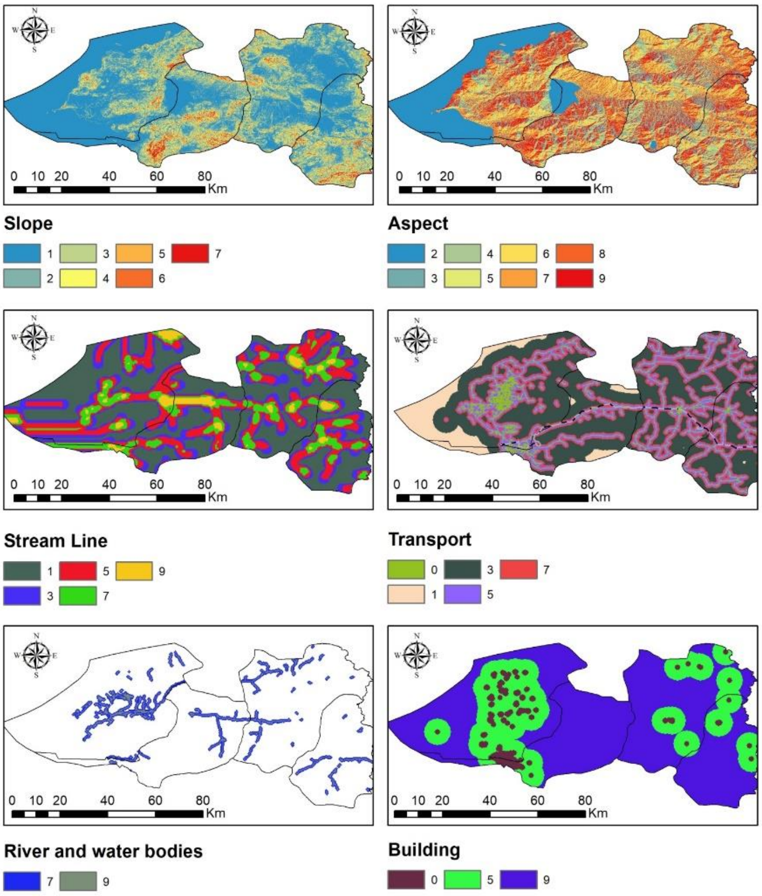

Figure 4. Slope(a), Aspect(b), Stream Line (c), Transport(d), River and water bodies (e), Building(f) criteria maps of the Study Area.

3.3. Result map

It has been taken into consideration that the existing railway route is important for the line in the region and is the basis of many disasters and that it is important in the examination of the criteria that these disasters adversely affect the railway transport. These considered parameters were examined in 6 classes as slope, aspect, stream, building, rivers and water bodies, transportation, and these criteria were processed in ArcGIS 10 program, superimposed, and processed with the criterion weights found in the Analytical Hierarchy Process (AHP) method, as shown in figure 5. Unsuitability points on the existing railway route have been identified.

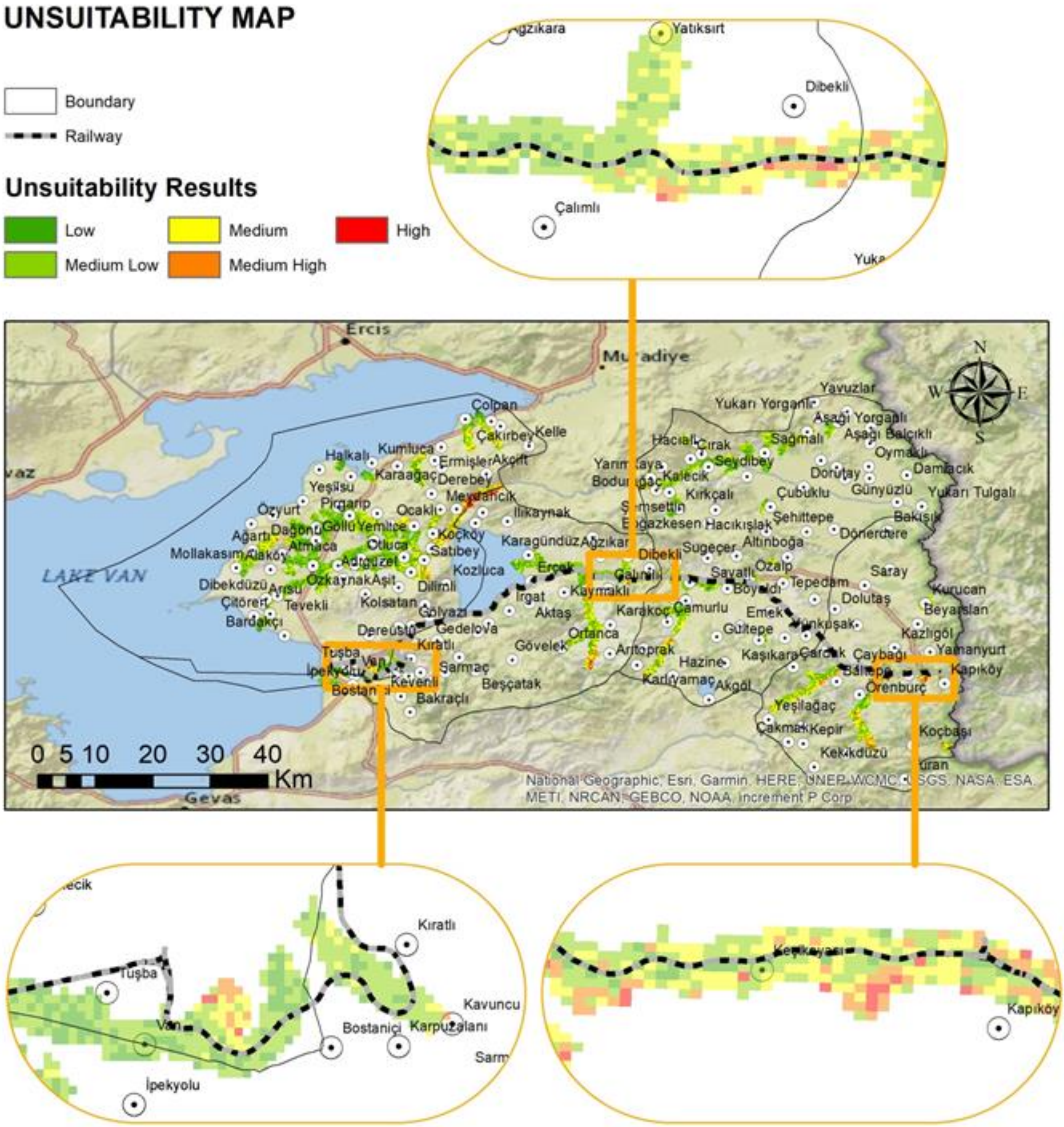

Figure 5. Unsuitability points on the railway route.

4. Discussion

Due to the location of the Van region, the elevation is very high and the topographical structure is covered with mountains, which has caused it to be a mountainous region, and also negatively affects the transportation sector in many ways because it is exposed to continental climatic conditions. In order to eliminate these disadvantages, natural conditions should not affect transportation. This, in turn, reveals the need to organize and structure the transport sector in a good way. As a result of the dec deconstruction of the necessary R&D studies, the necessary needs were not met by ignoring the natural factors that negatively affect the railway transportation. The existing railway route created as a result of ignoring these needs decays the rail geometry and causes wear on the balances. Due to the fact that it negatively affects railway transportation, it causes economic losses to people and institutions interacting with the railway. As a result of the natural disasters caused by the effects of these criteria on the distorted urbanization of the region, disruption of transportation and social and cultural destruction of the region and deformation of the line caused disruption of railway logistics. This, in turn, leads to the formation of financial losses in the country's economy. in order to eliminate this damage, it is necessary to study the criteria that should be considered. In this study, these criteria were examined and maps of the criteria were obtained. In these maps obtained, the highest risk areas were identified and inappropriate lines were identified and it was stated that this study should be taken into account in order to identify and prevent any material and moral losses caused by these inappropriate lines in advance.

5. Conclusion

In this article, the development of the railway, its importance, its indispensability for the world and our country, and its contributions to the logistics sector are emphasized. It has been mentioned that the necessary studies should be carried out for the efficient and effective use of the railway together with the globalization in the world and appropriate investments should be made to carry out these studies. The contribution of the railway in the country's economy and its importance for sustainable competition focuses on its economic and social contributions. It is emphasized how the railway line should be selected and how to choose this selection in the most appropriate way, and the computer systems and technology used in this selection, as well as the Geographic Information Systems (GIS) applications implemented together with the technology are mentioned.

In addition, the importance and place of the selected Van Lake- Kapıköy railway logistics line in the country's economy is mentioned. It is a mountainous region due to the location of the current route. For this reason, it is in a position open to disasters. This shows that the cost of the route is high and it is a risky factor. Efficiency, efficiency, economy, workability, standardization and similar advantages of Geographical Information Systems (GIS) applications are mentioned. The analysis of the risky areas on the route should be done in order not to disrupt the economic and logistics of the route used for freight transportation as a result of any negative effects of the criteria discussed as a result of the Geographical Information Systems (GIS) based examinations of the existing railway route that we discussed in this study. The criteria used as main data will be factors such as slope, aspect, stream, building, small water flow and transportation

The data sets of these factors were processed in the Geographic Information Systems (GIS) environment and as a result of the processing, certain values were given in line with the Analytical Hierarchy Process (AHP) method, which we applied, and these values were passed in the required processing stage of the method and the weights and normalized values of each criteria were calculated. Then, the values obtained as a result of the calculation were subjected to the consistency index and their suitability was examined. The suitability of the consistency index has been determined and appropriate, and a better and more useful line proposal of the railway line used for freight transport should be used for preliminary route planning and will be more useful. With the use of Geographic Information Systems (GIS) application, it is emphasized to provide maximum benefit and minimum cost. The unsuitability points on the route were determined by collecting, analysing, processing and reporting the most appropriate data as a result of the comparisons made based on the criteria selected in the Analytical hierarchy process method applied within the scope of Geographic Information Systems applications. In addition, the most appropriate use of the data obtained in line with these reports is mentioned.

Author Contributions

The contributions of the authors of this article is equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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