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QGIS-based Analysis of Traffic Accident Regions in Muratpasa District in Antalya City

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Keywords

Highway
Traffic Accident
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Abstract

The objective of this study is to identify the specific locations where traffic accidents occur in the Muratpasa district of Antalya province. Muratpaşa district is the most crowded area especially in tourism season. For this reason, it is important to analyse traffic accidents in this district. To this end, data from the years 2017 to 2021, obtained from the General Directorate of Security of the Republic of Turkey, were employed. The Quantum Geographical Information Systems (QGIS) program was used to ascertain the regions exhibiting elevated accident risk, while the Kernel Density Estimation method was used to categorize the accidents. Furthermore, the ages of drivers involved in accidents, the relationship between age and accident occurrence, the causes of accidents, and the distribution of accidents by years and months were subjected to statistical analysis. The accidents were categorized in four categories according to causes. The study revealed that the risk of traffic accidents was elevated in three distinct regions within the Muratpasa district. It was observed that most of these accidents involved individuals between the ages of 20 and 30, with the primary cause identified as driver error of traffic.

Cite

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1. INTRODUCTION

Traffic is a system that encompasses a multitude of fields, including transportation engineering, law, economics, urban and regional planning, sociology, and psychology. These fields collectively address the dynamic interaction of vehicles, pedestrians, and other road users. The contributions of these fields facilitate the provision of sustained and dependable transportation. A traffic accident can be defined as an event that disrupts the continuity of transportation as a result of unexpected and undesirable events on this road network, resulting in damage, injury or death to those involved in the accident.

The type and number of traffic accidents are influenced by a multitude of variables. The main factors include highway and environmental conditions, driver behavior, vehicle maintenance, and traffic density. The interaction, diversity, and complexity of these factors are investigated by using several methods. In recent years, data obtained with these methods have been widely analyzed with Geographic Information System (GIS) for accident analysis and prevention (Le et al., 2020; Sababhi et al., 2024; Sohaib et al., 2024). In addition to the use of GIS, statistical approaches such as Getis Ord Gi, Kernel Density Estimation, and Moran's are used in the analysis (Alam & Tabassum, 2023; Le et al., 2023).

Loo (2006) researched a spatial breakdown of accidents that occurred in Hong Kong between the years 1993 and 2004. To identify the regions in question, the researcher used three databases. These databases include accident regions, highway networks, and district councils. The author presented that the use of GIS enabled

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the reduction in the number of personnel required to verify the accuracy of the identified locations. Additionally, this process revealed that approximately 65-80% of the police accident records about traffic accidents were found to be accurate. In 2004, it was determined that 12.7% of the police accident database contained erroneous highway names and 9.7% exhibited incorrect county names in this study (Loo, 2006). Clifton and Kreamer-Fults examined the pedestrian-car accidents around public schools in Baltimore City, Maryland, the injuries sustained in such accidents, and the relationship between these injuries and the physical and social characteristics of the area in which the schools are located (Clifton & Kreamer-Fults, 2007). A geographic information system (GIS)-based study was prepared by Zhang and Shi in the Beijing area to identify the locations with the highest concentration of traffic accidents. In addition, in this study, by using accident data, it is shown that the hotspot area is related to the volume of traffic, the driver's condition, the number of intersections on the highways, and the vehicle information system as a cause of accidents at the micro level by distracting the driver. The spatial differentiation pattern of traffic accidents was analyzed by K-means clustering method (Zhang & Shi, 2019). A GIS was used to identify areas at high risk of traffic accidents by spatial autocorrelation analysis using four years of accident data in the Oromia region and surrounding towns in Ethiopia by Tola et al. Getis Ord Gi* analysis was used to cluster accident severities (Tola et al., 2021). Mesquitela et al. (2022) used GIS to determine the regions where traffic accidents in Lisbon are concentrated. Kernel Density Estimation and Getis-Ord Gi* analyses were applied in this study. The presence of hotspots was determined spatially and evaluated environmentally (Mesquitela et al., 2022).

Antalya is one of the most prominent tourist destinations in the region. The city's population is growing at a rapid rate. Additionally, Muratpasa is among the most ancient settlements in Antalya.

The objective of this study is to ascertain the regions exhibiting elevated accident risk through the utilization of the 'kernel density estimation' method, employing data on traffic accidents that occurred between 2017 and 2021 within the borders of the central district of Muratpasa, Antalya, Turkey, in QGIS, a GIS-based program. A study specific to this region has not been identified in the literature review in recent years. Furthermore, variables such as the ages of the drivers involved in accidents, the causes of accidents, the distribution of injuries and fatalities after accidents, and the distribution of accidents by months were analyzed. Additionally, the locations where accidents occurred due to insufficient 'stopping visibility distance' were identified.

2. MATERIAL AND METHOD

2.1. Study Area

The selected working area in this study was the Muratpasa district of Antalya province. The location of the region is shown in Figure 1. Furthermore, as shown in Figure 1, the highest population density in Antalya is observed in the city center, which is identified as the Muratpasa district. According to Turkish Statistical Institute data, the population of the district has been increasing in the last 5 years except 2023. The data indicate that the district's population was 510368 in 2019, 513035 in 2020, 521183 in 2021, 526293 in 2022, and 512700 in 2023 (Turkish Statistical Institute, nd). At the same time, the province receives many tourists during the summer season, which leads to an increase in traffic. As there are some tourist spots in these areas, the traffic becomes even more intense. This high population and traffic density in Muratpasa district shows that a traffic accident on the motorway in the region has a significant direct or indirect impact on many civilians.

2.2. QGIS Software and Kernel Density Estimation

In this study, the QGIS program was used to make analysis as well as visualize maps. The software is open to continuous development with its user-friendly interface, accessibility and open-source nature (Khan & Mohiuddin, 2018; Moyroud & Portet, 2018). All these reasons were effective in the use of QGIS in the study. For the interaction of accidents, the radius was set as 0.01 and the pixel size as 0.001.

To determine hotspots by using Kernel Density Estimation Analysis, the coordinates of the traffic accident were entered into the GIS program. Kernel Density Estimation Analysis is one of the most widely used methods, as the results obtained can be mapped spatially, and densities can be readily determined. In this method, the data within the selected radius are subjected to analysis, resulting in the calculation of the density. Consequently, a smooth conical surface is generated (Yigit Katanalp et al., 2023). This method differs from

others in that it does not depend on assumptions about the density of the data set. Instead, it directly examines the distribution of the data set and the cluster itself (Zhang et al., 2021). Moreover, the bandwidth selected in this method is of significant importance (Harirforoush & Bellalite, 2019).

$$f(x,y) = \frac{1}{n * h^2} * \sum_{i=1}^{n} K * (\frac{d_i}{h}) \quad (1)$$

In Equation 1, f(x,y) represents the density assumption for point x, h denotes the width of the band, n signifies the number of observations, d_i (x, y) is the distance between the selected location and it's location, and K is the coefficient (Anderson, 2009).

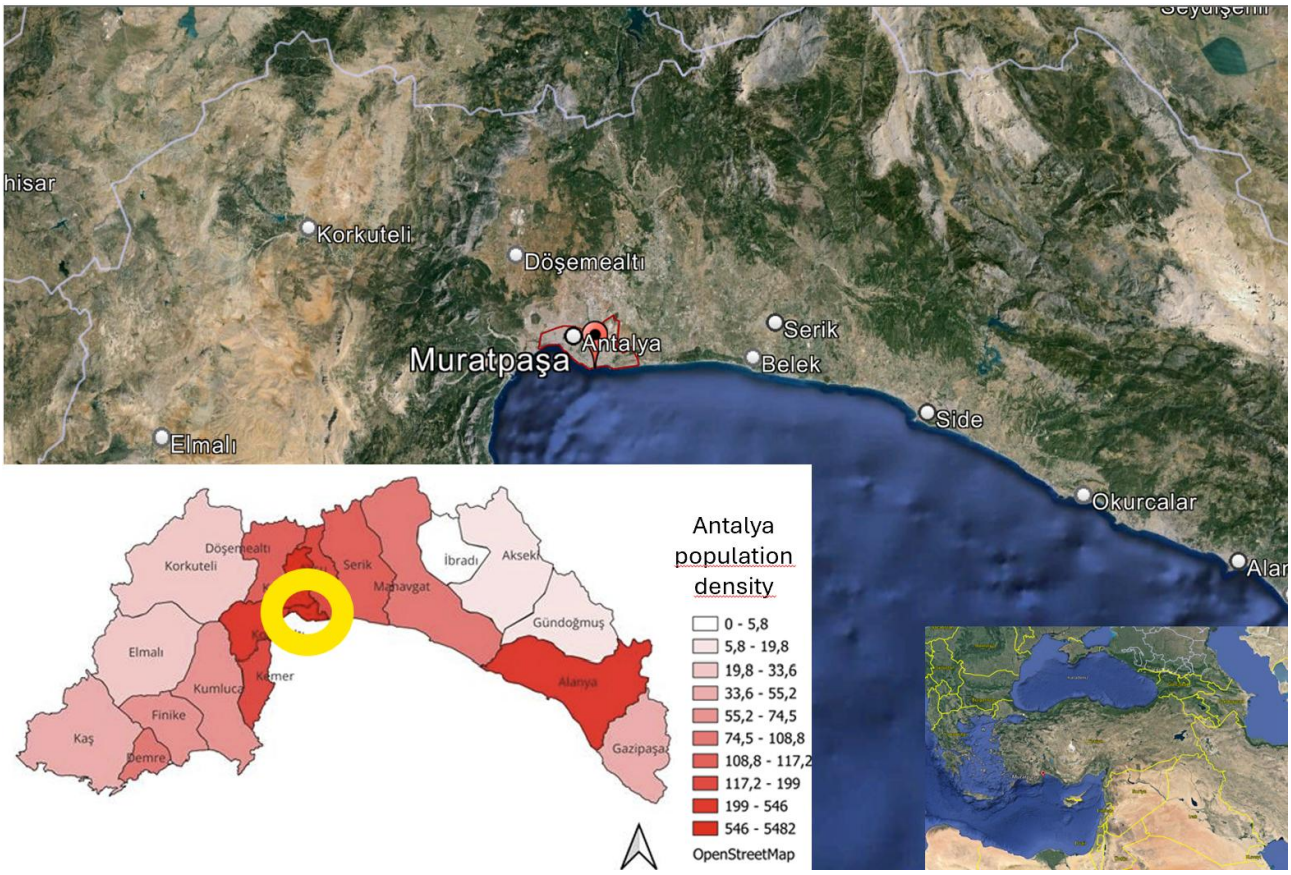

Figure 1. *Location of Muratpasa district and population density Antalya province*

2.3. Traffic Accidents Caused by Insufficient Sight Distance

It is of significant importance to consider the impact of sight distances on traffic safety when analyzing traffic accidents (Deng et al., 2008; Abdulhafedh, 2020). In traffic safety, several factors, such as the presence of trees and building corners, can impede drivers' visibility. This situation mostly results in traffic accidents. There are two primary categories of visibility deficiencies:

- Insufficient stopping sight distance,
- Insufficient overtaking sight distance.

Insufficient stopping sight distance

In this study, to analyze the Insufficient stopping sight distance effect on traffic accidents, the following accidents were selected based on data obtained from General Directorate of Security: those caused by rear-ending (accident number 1), failing to stop at a red light or stop sign (accident number 2), slowing down or

stopping in a way that disrupts traffic (accident number 3), and failing to slow down at pedestrian and school crossings or failing to give pedestrians the right of way (accident number 4).

In the QGIS program, the locations where accidents due to the reasons are concentrated were identified with heat maps. Equation 2 presents the stopping sight distances. The formula for the stopping sight distance is given in Equation 2, Equation 2 was employed in the creation of the table.

$$L_{fe} = 0{,}278 * V * t_r + 0{,}00394 * \frac{V^2}{f \pm s} \quad (2)$$

In Equation 2, V (km/h) represents the vehicle speed, t_r (sec) denotes the travel-reaction time, f is the coefficient of friction on the highway surface, and s is the slope of the highway. Due to the high rainfall in Antalya province in some seasons, the friction value on the platform decreases. In rainy weather, the f value drops to 0.35. The equation for the overtaking sight distance for no oncoming vehicles is given in Equation 3, and the formula for the overtaking sight distance for oncoming vehicles is given in Equation 4 (Yayla, 2004).

$$L_s = \frac{v_1 * (d_1 + d_2)}{v_1 - v_2} \quad (3)$$

In Equation 3, the variables v_1 and v_2 represent the speed of the vehicles, while the variables d_1 and $d_2$represent the following distances.

$$L_s = \frac{v_1 * (d_1 + d_2)}{v_1 - v_2} + v_3 * \frac{(d_1 + d_2)}{v_1 - v_2} \quad (4)$$

In Equation 4, the symbols v_1 and v_2 represent the speed of vehicles traveling in the same direction, while the symbol v_3 represents the speed of the approaching from the opposite direction. The symbols d_1 and d_2 represent the following distances of vehicles traveling in the same direction.

2.4. Age of drivers involved in accidents and the relationship between age-accidents

In a study conducted using data on traffic accidents that occurred in Hosanna Town between 2015 and 2017, it was determined that the age range between 18 and 30 was the highest in traffic accidents (Hayidso et al., 2019).

In this study, an age analysis was conducted to examine the distribution of driver ages in traffic accidents in the region.

2.5. Causes of accidents

In a study conducted on the Lokoja-Abuja-Kaduna highway in Nigeria, it was observed that the most common cause of accidents was drivers violating the speed limit (Afolayan et al., 2022).

The causes of accidents were evaluated according to four main categories: speed-related accidents, accidents thought to be caused by lack of attention, accidents caused by non-compliance with the rules, and traffic accidents caused by other reasons.

2.6. Situation after the accident

In a study conducted in Karabük, the occurrence of black spots was identified through the analysis of data on traffic accidents that occurred between 2013 and 2017. In the same study, the health status of individuals involved in the accidents was examined, and it was determined that 0.38% of the accidents resulted in death, 61.52% in injury, and 35.11% in material damage (Doğru & Aydın, 2018).

In this study, the situation after the accident was examined under 5 main headings. These are:

1. Fatal accident,
2. Accident with injury,
3. Safe (no deaths or injuries) accident,
4. The driver is not in the vehicle, or the vehicle is parked.
5. Vehicle driver escapes from the accident area

3. RESULTS AND DISCUSSION

In this study, initially accident risk zone map was created by using QGIS. This map shown in Figure 2 was created using data on traffic accidents that occurred in the Muratpasa district. The coordinates of the regions with a high risk of accidents are shown in Figure 2 as the red region.

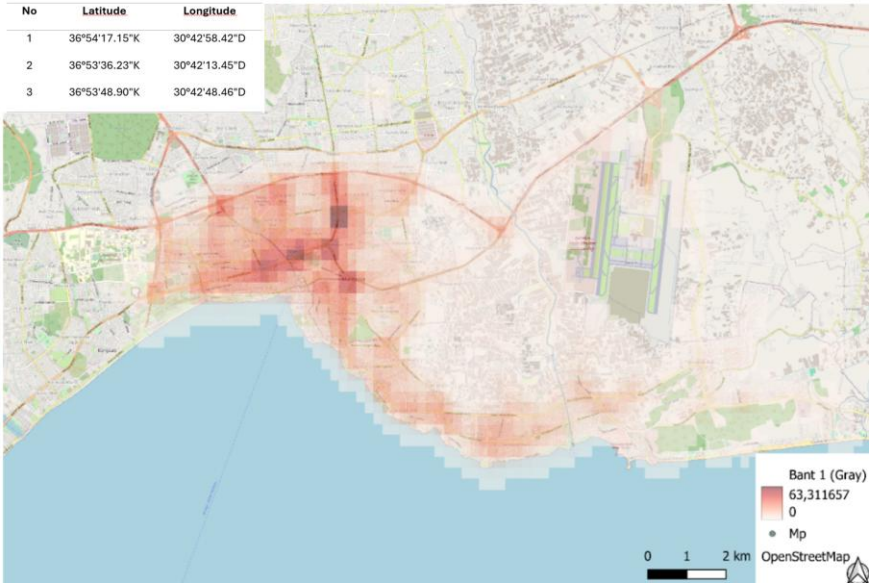

Figure 2. *Accident risk zone map*

To traffic accident analysis encompassed several parameters, not only including the place where the traffic accident occurred but also including the age of the drivers involved in the accident, the relationship between age and accident, the causes of the accident, the situation after the accident, and the distribution of accidents by month.

Age of drivers involved in accidents and the relationship between age-accidents

In this study, an age analysis was conducted to examine the distribution of driver ages in traffic accidents in the region. Furthermore, the potential correlation between the age of drivers involved in accidents in the region and the occurrence of such incidents was investigated through a correlation analysis conducted using the SPSS statistical software. Figure 3 shows the age distribution of drivers involved in traffic accidents in the Muratpasa district.

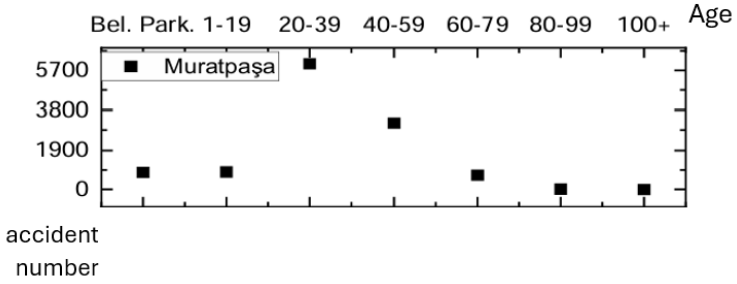

Figure 3. *Age distribution of drivers involved in traffic accidents*

In this study, drivers aged 20-39 years were found to be involved in the highest number of accidents, while drivers aged 40-59 years showed the second-degree highest level of involvement. In a study conducted using data on traffic accidents that occurred in Hosanna Town between 2015 and 2017, it was determined that the age range between 18 and 30 was the highest in traffic accidents (Hayidso et al., 2019). The results obtained are consistent with this study. This situation shows that more young drivers are involved in traffic accidents. This may have various reasons such as their novice driving and their tendency to drive fast. Figure 4 shows the graph of the health status of the individuals involved in the accident after the accident.

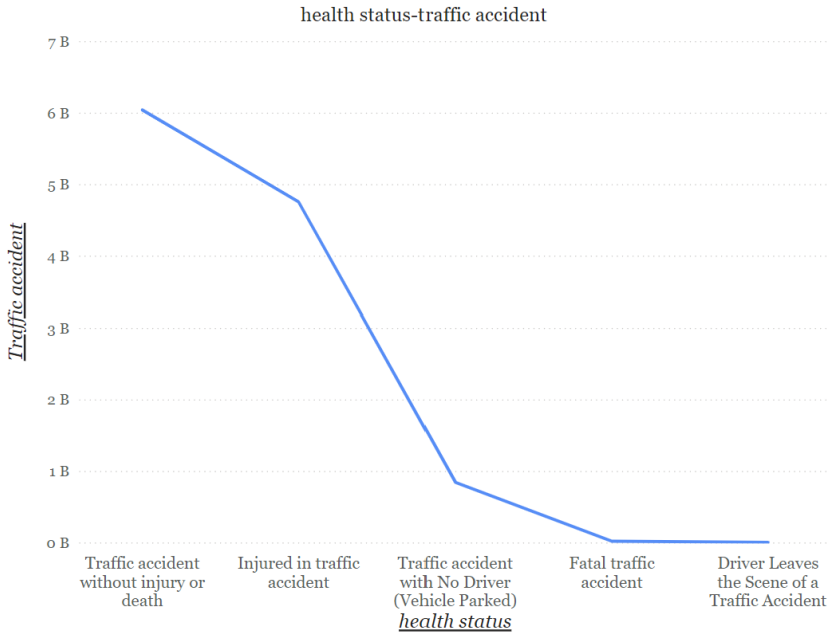

Figure 4. *Health status of individuals involved in traffic accidents*

A study conducted in Karabük identified that 0.38% of traffic accidents in that province resulted in fatalities, 35.11% in material damage, and 61.52% in injuries (Doğru & Aydın, 2018). In the study, the underlying causes of traffic accidents in the Muratpasa district of Antalya province were determined as drivers' failure to comply with the established rules, excessive speed, inattention and other contributing factors. It can be said that 95% of all traffic accidents do not result in death.

Causes of accidents due to lack of vision

In this study, firstly data related to the reason for accidents were grouped into two categories according to sight distance: The accidents caused by insufficient stopping sight distance and accidents caused by insufficient overtaking sight distance. Then, data related to causes of accidents based on stopping sight distance were numbered as below:

1. Reported as speed-related accidents (commonly caused by stop-and-go is the driver's failure to stop despite the light or officer's stop signal)
2. Accidents reported to be caused by lack of attention
3. Accidents reported as caused by non-compliance with the rules
4. Traffic accidents reported as caused by other reasons

Figure 5 shows the risk map of traffic accidents caused by insufficient stopping distance in the district. It has been determined that the most common cause of traffic accidents caused by stop-and-go is the driver's failure to stop despite the light or officer's stop signal. In a study conducted on the Lokoja-Abuja-Kaduna highway in Nigeria, it was determined that the most common cause of accidents was drivers violating the speed limit (Afolayan et al., 2022). In other words, accidents due to speed and accidents due to the vehicle's inability to stop because of speed occur frequently, as seen in this study. Also Figure 6 shows the accidents caused by insufficient overtaking sight distance

Figure 5. *Accidents caused by insufficient stopping sight distance*

Distribution of accidents by years and months

In this study, the distribution of traffic accidents by month was examined and the month in which the greatest number of accidents occurred was determined. The incidence of traffic accidents varies considerably between different regions and months. For example, a study revealed that the majority of traffic accidents occur during the winter season (Le et al., 2020). In a separate study, the occurrence of traffic accidents was determined to be particularly prevalent during the summer months. Because the intensity of traffic varies depending on the characteristics of the region. Antalya is the biggest tourism city in Turkey. Especially in summer, the population of Antalya increases by approximately doubled. As can be seen in Figure 6 the greatest number of traffic accidents in the district occurred in July. The lowest number of accidents was recorded in February. The data indicates that the highest number of traffic accidents in the district occurred in 2021.

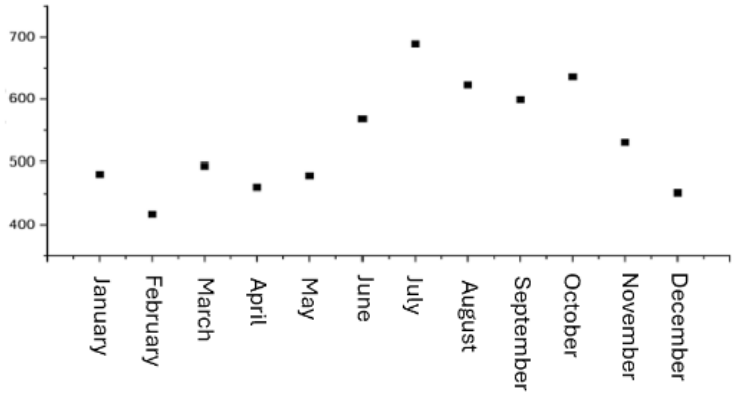

Figure 6. *Distribution of accidents by months*

4. CONCLUSION

The objective of this study is to identify the specific locations within the Muratpasa district of Antalya province that are most prone to traffic accidents. The Quantum Geographic Information System (QGIS) program was employed to facilitate the comprehension of the regions exhibiting a concentration of accidents. The regions where traffic accidents are concentrated are indicated by a dark red coloration. The results indicated that traffic accidents are concentrated in intersection areas.

The study revealed that the age group most frequently involved in traffic accidents in the Muratpasa district was that of individuals between the ages of 20 and 39. Given that Muratpasa district is an established settlement with a concentration of entertainment venues, it has been determined that the majority of traffic accidents occur

during periods of increased tourism. It has been determined that the majority of road traffic accidents are caused by driver errors. These include speeding, failure to comply with traffic regulations and driving under the influence of alcohol. The study also revealed that approximately 52 out of 100 individuals involved in accidents survived without injury, while seven accidents resulted in injury. Furthermore, the regions within the Muratpaşa district where accidents resulting from inadequate insufficient stopping sight distance were concentrated were identified. The analysis indicates that accidents caused by inadequate stopping visibility are concentrated in two regions.

As a result of all these findings, traffic control can be tightened in some accident-prone areas.

In addition, some factors may lead to incorrect data being entered at the scene. For example, latitude and longitude values in coordinate data may be confused. In such cases, the data should be checked and investigations carried out.

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AUTHOR CONTRIBUTIONS

Conceptualization, Sevil Köfteci and Mehmet Arikan Yalcin ; methodology, Sevil Köfteci and Mehmet Arikan Yalcin ; fieldwork, Sevil Köfteci and Mehmet Arikan Yalcin .; software, Mehmet Arıkan Yalçın and Sevil Köfteci; title, Sevil Köfteci and Mehmet Arikan Yalcin ; validation, Sevil Köfteci and Mehmet Arikan Yalcin ; laboratory work, Sevil Köfteci and Mehmet Arikan Yalcin .; formal analysis, Sevil Köfteci and Mehmet Arikan Yalcin ; research, Sevil Köfteci and Mehmet Arikan Yalcin ; sources, Sevil Köfteci and Mehmet Arikan Yalcin ; data curation, Sevil Köfteci and Mehmet Arikan Yalcin .; manuscript-original draft, Sevil Köfteci and Mehmet Arikan Yalcin ; manuscript-review and editing, Sevil Köfteci and Mehmet Arikan Yalcin ; visualization, Sevil Köfteci and Mehmet Arikan Yalcin .; supervision, Sevil Köfteci and Mehmet Arikan Yalcin ; project management, Sevil Köfteci and Mehmet Arikan Yalcin ; funding, Sevil Köfteci and Mehmet Arikan Yalcin . All authors have read and legally accepted the final version of the article published in the journal.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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