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Humidity-Induced Deterioration in Traditional Buildings: A Case Study of İspir, Türkiye

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Abstract

Traditional structures, which are historical documents, are subject to deterioration due to lack of regular maintenance, changes in function, and the effects of environmental conditions. In this research, indoor and outdoor humidity measurements were carried out in six traditional structures located in Petekli and Varkur villages of İspir district in Erzurum province, Turkey. The effect of humidity on structural deterioration was evaluated through on-site observation and documentation. The obtained indoor and outdoor relative humidity and temperature data obtained were analyzed within the context of the structures' location, usage, and environmental conditions; accordingly, the effect of ambient humidity on structural deterioration was analyzed. The findings show that humidity-induced deterioration in the examined structures is concentrated in the sections of the walls in contact with the ground and on the north and northeast facades, which receive less sunlight. Based on these results, identifying and controlling sources of humidity and implementing preventive interventions are crucial in conservation efforts.

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INTRODUCTION

Traditional and vernacular buildings, as one of the components of cultural heritage, serve as documents reflecting the climatic conditions of their geography, the use of local materials, traditional construction techniques, and social lifestyles. Traditional structures can be defined as a multidimensional field of knowledge and practice shaped by the development and application of construction techniques and empirical knowledge passed down orally through generations. Traditional structures are a concrete reflection of environmental conditions, the building materials used, and the sociocultural characteristics of communities (Ünlü, 2025). These buildings have an important function not only with their architectural features but also in preserving rural identity and ensuring the continuity of cultural continuity.

Over time, as a result of technological developments, urbanization processes, and changing living conditions, vernacular architecture has been largely ignored with the rise of modern architecture in the West. Traditional building culture, during the period when the concept of modernization was influential, was seen as a reflection of underdeveloped societies and was not considered a sufficient design input for contemporary architecture. Nevertheless, architects such as Alvar Aalto, Frank Lloyd Wright, and Luis Barragán aimed to develop an understanding that integrated climatic and cultural values specific to the local environment with modern architecture in their designs. However, architectural approaches that prioritize local identity only gained visibility after the 1970s (Özkan, 1992).

As urbanization accelerated, the population in rural areas decreased, and changes in living needs resulted in traditional structures being unable to maintain their existing functions or being abandoned. Buildings that were not actively used for a long time and did not receive regular maintenance became more vulnerable to environmental factors. In particular, factors such as humidity, precipitation, and temperature changes accelerate the deterioration process, negatively affecting the physical and aesthetic integrity of traditional structures.

The speed and severity of the deterioration process in structures vary depending on factors such as environmental and climatic conditions, the properties of the building materials used, and the frequency of maintenance. Among the

deteriorations that threaten the physical integrity of structures, the humidity factor stands out because it prepares the ground for the formation of other deterioration mechanisms and affects multiple materials. Moisture-related deterioration, which has been observed worldwide, has been identified through studies of architectural heritage structures as one of the primary causes of deterioration, particularly in buildings with brick walls (Falchi et al., 2018). Among the various external factors causing moisture formation in buildings are atmospheric precipitation, condensation, water leakage, and the hygroscopicity of materials (Guolo et al., 2023). In an environmental context, factors affecting a building's water absorption include the properties of the materials used (porosity, permeability, mineral composition, water absorption capacity, etc.), wall thickness, location and duration of moisture exposure, climatic conditions, salt accumulation, freeze-thaw cycles, ventilation, the building's intended use, and intensity of use (Guolo et al., 2023). Although exposure to these factors in traditional buildings leads to moisture-related deterioration, studies evaluating this deterioration in relation to current moisture conditions are limited.

In this research, indoor and outdoor humidity measurements were conducted in six traditional structures located in Petekli and Varkur Villages (Güllübağ Neighborhood) in the İspir district of Erzurum province. The observed deteriorations were documented through on-site inspections. Based on the data obtained, the relationships between the locational characteristics of the structures, climatic conditions, active use of the structures, and humidity levels were evaluated. Consequently, the effects of humidity on physical deterioration and indoor conditions were investigated.

Aim of the Study

This study aims to determine how humidity affects the physical integrity of six traditional structures with stone and adobe construction systems located in Petekli Village and Varkur Village (Güllübağ Neighborhood) in İspir, Erzurum, by measuring their indoor and outdoor humidity levels. In this context, the formation of humidity-induced deteriorations was examined by combining humidity measurements and on-site observations carried out in the six selected traditional structures.

Within the scope of the study, the relationship between indoor and outdoor humidity values and the effects of the locational and environmental characteristics of the structures on humidity levels were examined; the reflections of humidity on indoor air quality and user comfort were analyzed holistically. Accordingly, humidity-induced deteriorations on the structure such as stagnant water formation, mold and fungus growth, surface wetting, salt efflorescence, paint and plaster losses, deterioration in wooden elements, corrosion formations, condensation problems, material losses, cracks, stratification, and color changes were evaluated. Based on the data obtained, the aim was to reveal the environmental performance of traditional structures, identify moisture-related risks, and develop recommendations for the preservation of rural architectural heritage.

LITERATURE REVIEW

The study conducted by Zor and Soyluk (2026) examines the deterioration of historical structures due to climate change. In the research, 15 articles published in the Web of Science database between 2000 and 2025 were evaluated using the literature review method. As a result of the research, it was seen that climate change poses a significant threat by accelerating physical, chemical and biological deterioration in historical structures through temperature, humidity, extreme weather events and biological factors. As a result of the analyses, it was observed that academic studies on historical deterioration due to climate change increased after 2020. Holistic conservation approaches including climate change-adaptive conservation strategies, digital documentation and artificial intelligence-supported analysis methods were proposed for the preservation and transmission of cultural heritage to future generations.

Kuzuimamlar (1995), in her thesis, addressed a systematic study on the diagnosis and solution methods of moisture problems occurring in masonry historical structures. Within the scope of the research, moisture sources, the deterioration caused by moisture in building materials and the processes of determining moisture damage were examined. The research emphasized that periodic monitoring and control practices are critical in addressing moisture problems, and a flowchart for identifying moisture sources was proposed.

In their study, Šťastný et al. (2021), consider deterioration caused by rising humidity in historical buildings as a significant problem in terms of cultural heritage preservation and sustainability. They examined interventional and non-interventional dehumidification methods applied to various historical buildings in Slovakia; their effectiveness, application costs, and long-term results were evaluated. The findings reveal that appropriate humidity control and remediation methods contribute to the preservation of historical buildings and support their sustainable use.

Park (1996) comprehensively examined the diagnostic methods and intervention approaches for moisture-induced deterioration in historical buildings. The study evaluated the damage caused by moisture to building materials and proposed a systematic diagnostic approach for identifying moisture sources. The research concluded

that improving drainage, controlling moisture sources, ensuring adequate ventilation, and regular maintenance practices are effective in reducing moisture damage.

The study by D'Agostino (2013), examines the deterioration caused by humidity in historical buildings, particularly in masonry wall systems. The study investigated the rising humidity behavior in the Lecce Cathedral and its crypt area; humidity transfer processes were evaluated through modeling and experimental measurements. The findings showed that humidity movements and drying processes can be determined using microclimate data, and that this information is important for the preservation of historical buildings and the development of maintenance strategies.

Sawdy and Price (2005) investigated the relationship between salt-induced deterioration in historical buildings and environmental conditions. The study examined salt deterioration observed in 13th-century frescoes in the Sacrament of Cleeve Abbey in England. The study determined that salt formation varied depending on temperature and relative humidity changes. The research concluded that environmental monitoring and moisture control are effective in reducing salt-induced deterioration.

Torres and Peixoto de Freitas (2007) examined intervention methods for addressing rising humidity problems in historical buildings. The study indicated that traditional humidity control techniques were insufficient in thick and heterogeneous walls. Within the scope of the study, the wall base ventilation method, developed to control rising humidity in historical building walls, was evaluated through experimental and numerical analyses. The results showed that wall base ventilation is an effective intervention method in reducing rising humidity.

In their research, Beşkonaklı and Ersen (2012) examined preventive conservation and preventive maintenance approaches in the preservation of historical buildings using the Dolmabahçe Palace as an example. The study considered environmental risk factors such as humidity, microclimate, soluble salts, light, and biological deterioration. The research concluded that high relative humidity causes decay and biological deterioration in wooden elements and salt crystallization in walls; a conservation program based on regular monitoring, preventive maintenance, and control of environmental conditions was proposed for the sustainable preservation of historical buildings.

In a study conducted by Michalak and Graczyk (2020), moisture problems were examined in a historical residential building in Gubin, Poland. The study measured the moisture content of different elements in the building and evaluated the effects of excessive moisture. The findings emphasized the importance of moisture diagnosis in understanding deterioration processes and highlighted the need for appropriate intervention strategies for the preservation of historical buildings affected by excessive moisture.

In a study conducted by Li et al. (2021), the rate and height of rising damp in solid and hollow-core wall structures were examined; a 600-day laboratory experiment was carried out on two walls constructed of clay brick and lime mortar. The findings showed that the height of rising damp in the hollow-core wall was 192 cm, while in the solid wall it was 168 cm. This indicates that the type of building has a direct effect on rising damp.

The research conducted by Blaschke et al. (2023) aims to determine the moisture and salt content in historic building materials using a non-destructive and salt-independent method. In this context, measurements were performed on samples of historic building materials containing salt using ground-penetrating radar (GPR) in the 1–3 GHz frequency range. The findings indicate that moisture content can be determined independently of salt content within the selected frequency range, and that the salt level in the materials can be quantitatively identified.

The article prepared by Franzoni (2018) aimed to examine existing technologies and methods for mitigating rising damp in historic masonry structures and to evaluate the effectiveness of these methods. In this context, existing methods were evaluated by reviewing research findings obtained from laboratory and field studies involving various technologies and materials. The study concluded that, although various technologies have been developed to eliminate rising damp, data on the effectiveness of these methods under actual building conditions is limited, and the reasons for their success or failure have not yet been fully explained.

In a study by Eroğlu and Halaç (2022), the long-standing problem of rising moisture in the İnce Minareli Medrese in Konya was examined, and solutions were proposed for moisture-induced deterioration in historical buildings. The study utilized on-site observation, literature review, and archival research methods. The study evaluated moisture sources, moisture-induced deterioration, and repairs the building has undergone. The literature review revealed that moisture is one of the most common causes of deterioration in historical buildings. The research addressed the effects of rising moisture, soluble salts, biological deterioration, and environmental conditions on building materials. In this regard, early detection and regulation of humidity problems are crucial.

A literature review revealed that existing studies focus on the diagnosis and measurement of moisture problems in historic buildings, the mechanisms of moisture accumulation, moisture removal methods, salt efflorescence, and conservation practices. Table 1 lists the objectives, methods, findings, and focal points of the articles examined. Based on an analysis of the articles' focal points, it was concluded that there are relatively few studies that evaluate current moisture conditions in traditional rural structures using field data and that address the indoor and outdoor

relative humidity values of different buildings in conjunction with observed physical deterioration. In particular, the lack of studies examining the moisture conditions and moisture-related deterioration of traditional buildings in rural settlements in the Eastern Anatolia Region through on-site observations and comparative moisture measurements is noteworthy. Specifically, the aim of this study is to evaluate the humidity conditions causing humidity-related deterioration in rural architecture through on-site measurements of indoor and outdoor relative humidity, taking into account the buildings' usage status and observed physical deterioration, and to fill the research gap in the literature regarding humidity-related deterioration in traditional rural structures.

Table 1. Literature Review Table

Author(s)	Aim	Method	Findings	Key Focus
Kuzuimamlar (1995)	Examining methods for diagnosing and solving moisture problems in masonry structures.	Literature review, evaluation of moisture sources and intervention methods.	The importance of accurate diagnosis in solving humidity problems has been emphasized, and a systematic approach to identifying the source of humidity has been proposed.	Diagnosis and intervention
Eroğlu and Halaç (2022)	To assess the rising humidity problem in the İnce Minareli Madrasa.	On-site investigation, literature and archive review, oral interviews.	Moisture sources and deteriorations have been identified, and protection and intervention recommendations have been developed using similar examples.	Rising Humidity – Single Structure
Michalak and Graczyk (2020)	Measuring moisture content in a historical building to assess moisture-related problems.	Humidity measurements and field work.	It has been stated that moisture diagnosis is important for understanding deteriorations and developing appropriate protection strategies.	Moisture measurement
Torres and Peixoto de Freitas (2007)	To investigate the effectiveness of wall base ventilation methods against rising humidity in historical buildings.	Experimental studies and numerical analyses	Under-wall ventilation methods have been shown to be effective in reducing rising humidity.	Intervention method
Beşkonaklı and Ersen (2012)	To evaluate preventive conservation and maintenance practices at Dolmabahçe Palace.	Risk analysis, environmental monitoring and situation assessment.	High humidity has been found to cause deterioration in wood and wall surfaces, highlighting the importance of regular monitoring and maintenance.	Preventive conservation and maintenance
Sawdy and Price (2005)	Examining the relationship between salt-induced degradation and environmental conditions.	Salt analyses, environmental monitoring, and the ECOS model.	It has been determined that salts are affected by changes in temperature and relative humidity, and that humidity control is effective in reducing deterioration.	Salinization + environmental conditions
Park (1996)	Examining moisture sources and conservation methods in historical buildings.	Literature review and case evaluations	Systematically identifying sources of moisture has highlighted the importance of drainage, ventilation, and maintenance practices.	Moisture sources + conservation
Zor and Soyluk (2026)	This study aims to evaluate the effects of climate change on the deterioration of historical structures and the research trends in this field.	In this study, research published in the Web of Science database between 2000 and 2025 was examined using bibliometric analysis and literature review methods.	The study concluded that climate change accelerates various deteriorations in historical structures, that research has increased especially since 2020, and that climate-friendly strategies and digital documentation methods have gained importance in the preservation of cultural heritage.	Climate change
Šťastný et al. (2021)	Evaluating moisture-induced deterioration in historical buildings within the scope of sustainable conservation.	Investigation of different dehumidification technologies, cost and effectiveness analyses.	The contribution of appropriate humidity control methods to conservation and sustainable use	Sustainable conservation
D'Agostino (2013)	To evaluate the effect of rising humidity on the deterioration of masonry wall systems in historical buildings.	Moisture movements in the Ecce Cathedral and crypt area were modeled and investigated with experimental measurements.	It has been shown that humidity behavior can be determined using microclimate data and contributes to conservation and maintenance decisions.	Rising humidity + masonry wall
Li et al. (2021)	To determine the effect of different building types on the rate of moisture rise and rise height in masonry walls.	A water level rise experiment was conducted in a laboratory setting for 600 days on two solid and hollow walls constructed from clay bricks and lime mortar, measuring 3 m x 1.2 m x 0.24 m.	At the end of the experiment, the height of the rising humidity was measured as 192 cm in the hollow wall and 168 cm in the solid wall, and it was determined that the building type directly affects the rate and height of humidity rise.	Rising humidity

Author(s)	Aim	Method	Findings	Key Focus
Blaschke et al. (2023)	To enable the determination of moisture and salt content in historical building materials using a non-destructive and salt-independent method.	Frequency-dependent complex dielectric permittivity measurements were performed on historical building materials containing salt in the historical structure using ground penetrating radar (GPR) in the 1–3 GHz frequency range.	It was concluded that in the 1–3 GHz frequency range, the amount of moisture, independently of salt content, and also the salt level in the materials can be quantitatively determined.	Moisture and salt detection
Franzoni (2018)	The aim of this study is to examine existing technologies and methods for eliminating rising damp in historical masonry structures and to present the current situation by evaluating the results obtained from laboratory and field studies.	Existing methods were evaluated comparatively by examining the research results obtained from laboratory and field studies.	Although various technologies have been developed to address the rising humidity in historical buildings, data on the effectiveness of these methods under real building conditions is limited.	Eliminating rising humidity.

METHODS

This study aims to identify moisture-induced deterioration observed in traditional structures and to evaluate the effects of moisture conditions on the structures. Six traditional structures in the İspir region were selected for evaluation based on moisture damage. Indoor and outdoor relative humidity measurements were taken in the selected structures. As a result of the literature review, a series of indicators related to visible and hidden moisture damage were identified. These indicators were used as observational assessment criteria in the fieldwork to evaluate the deterioration in the structures under study. Hidden moisture was not measured directly using any device. On-site observations were carried out to identify signs of visible and latent moisture damage. The relationship between the deterioration and moisture was analyzed by evaluating the measurement results and the data obtained from on-site observations together. When evaluating moisture-induced deterioration, the indicators determined in the literature study on the detection of moisture damage in historical and traditional structures were taken as the basis. While determining the evaluation criteria, an observation table for the field study was prepared by referencing the moisture sources, deterioration mechanisms and damage indicators included in the studies of Park (1996), Eroğlu and Halaç (2022) and Ünlü (2025). The evaluation criteria are; Biological deterioration (mold, fungus, and moisture formation), surface deterioration (staining, discoloration, salt efflorescence, blistering, and stratification), material loss (abrasion, disintegration, and mortar loss), structural deterioration (cracks, deformations, and material separation), deterioration observed in wood and metal elements (decay, rusting, and corrosion), signs of condensation, and problems related to drainage and roof systems were defined. In accordance with the determined evaluation criteria, the deteriorations observed in the six traditional structures examined were recorded in tabular form and evaluated together with the relative humidity measurement results.

Characteristics of the Study Area

The İspir district, located in the Erzurum province in eastern Turkey, was selected as the study area. Due to its location, the İspir region, rich in traditional architecture and construction techniques, is among the settlements that have preserved their traditional structures to the present day. The harsh climate conditions of the İspir district, its exposure to long winters, and high humidity levels negatively affect the material durability of the structures in the region. In addition, the abandonment of structures due to migration and the lack of regular maintenance are directly related to the physical integrity of the structures. These characteristics allow for the more pronounced observation of moisture-induced deterioration, salinization, biological formations, and material losses in traditional building materials such as stone, adobe, wood, and mortar. Therefore, the İspir district was selected as the study area.

Geographical Location and Climate of Erzurum

Erzurum is located in the northeast of the Eastern Anatolia Region, between 39 degrees North and 41 degrees East longitude. Figure 1 shows Erzurum's location in Turkey. Bordering Ağrı, Ardahan, Artvin, Bayburt, Bingöl, Erzincan, Kars, Muş, and Rize, Erzurum province has a surface area of 25,355 km². Its altitude is 1850-1890m above sea level (Yiğit, 2023). According to 2025 data, its population is estimated at 745,005 (Nufusu.com, 2025). Erzurum province has 20 districts, which are shown in Figure 2.



Fig. 1. Erzurum's location in Turkey
(Map taken from Google Maps Edited by the author.)



Fig. 2. Map showing the districts of Erzurum.
(Edited by the author using paintmaps.com as a reference.)

Table 2. Erzurum climate statistics

ERZURUM	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Measurement Period (1929 - 2025)													
Average Temperature (°C)	-9,1	-7,6	-2,3	5,4	10,7	14,9	19,2	19,6	14,8	8,2	1,2	-5,7	5.8
Average Highest Temperature (°C)	-3,9	-2,3	2,7	11,1	16,9	21,9	26,6	27,4	22,8	15,3	6,9	-0,8	12.0
Average Lowest Temperature (°C)	-13,9	-12,6	-7,0	0,1	4,3	7,3	11,1	11,2	6,4	1,7	-3,8	-10,2	-0.4
Average Sunshine Duration (hours)	3,4	4,5	5,2	6,3	7,9	10,2	11,2	10,7	9,1	6,9	4,9	3,2	7.0
Average Number of Rainy Days	11,15	10,93	12,49	13,76	16,03	10,91	6,79	5,15	5,11	9,45	9,12	10,59	121.5
Average Total Monthly Rainfall (mm)	21,3	25,3	35,4	55,1	73,3	48,2	28,8	17,5	23,9	46,9	33,0	21,8	430.5
Measurement Period (1929 - 2025)													
Highest Temperature (°C)	10,4	10,6	21,4	26,5	29,6	32,3	35,6	36,5	33,6	27,0	20,7	14,0	36.5
Lowest Temperature (°C)	-36,0	-37,0	-33,2	-22,4	-7,1	-5,6	-1,8	-1,1	-6,8	-14,1	-34,3	-37,2	-37.2

Daily Total Highest Rainfall Amount	Daily Fastest Wind	Highest Snowfall
02.04.2007 **70,8 mm**	09.04.2025 **30,9 m/sn**	23.02.2004 **110 cm**

Source: (General Directorate of Meteorology, 2026)

According to data obtained from long-term observations conducted by the General Directorate of Meteorology between 1929 and 2025, Erzurum province is located in a geography exhibiting distinctly harsh continental climate characteristics. Considering the long-term climate data shown in Table 2, it can be said that the formation of the region's climatic identity is influenced by seasonal changes as well as geographical factors such as landforms, altitude, and inland location.

Based on the data obtained, the climatic character of Erzurum province includes sudden seasonal changes throughout the year and high differences in temperature values. Winter months in the region are long and severe, with continuous frost events. Although temperature values rise in the summer season, they are short-lived. As a reflection of the region's climatic character, the temperature difference between day and night continues even in the summer months. This situation is also among the characteristics of a continental climate.

According to the data provided by the General Directorate of Meteorology, the average annual temperature in the region is measured as 5.8°C. This value shows that the average temperature of the region is lower than the average for Turkey. Looking at the values given in the table, sharp temperature drops in the winter months are noteworthy. The average temperature measured in January was -9.1°C, and the average lowest temperature was -13.9°C. In February, these values increased to -7.6°C and -12.6°C. This situation leads to persistent frost events and the formation of a long-term snow cover. Temperatures rise relatively during the summer months. In July and August, average temperatures reach 19.2°C and 19.6°C respectively, with average highest temperatures reaching 26.6°C and 27.4°C. Despite this, the fact that nighttime temperatures hover around 11°C during the summer months supports the conclusion that temperature variations are significant in Erzurum.

Looking at the highest and lowest temperature values, the harsh and continental climate characteristics of Erzurum province are clearly evident. When examining extreme temperature values, the lowest temperature recorded was -37.2°C, and the highest was 36.5°C. There is a difference of 73°C between these temperatures. Such high temperature differences directly affect material behavior, expansion and contraction processes, and the durability of the building envelope. In particular, the intensity of freeze-thaw cycles caused by temperature changes poses a threat to the physical integrity of building materials.

Examining the precipitation amounts in Table 2, the total annual precipitation is recorded as 430.5 mm. This value, lower than the Turkish average, is characteristic of a semi-arid continental climate. The highest rainfall occurs in the spring. The average total rainfall in May is 73.3 mm. In contrast to spring, rainfall is lowest in the summer months. The average total rainfall in August is 17.5 mm. These values indicate that the distribution of rainfall throughout the year is not homogeneous. Wind data is also an important element that complements Erzurum's climatic character. The measured maximum wind speed of 30.9 m/s shows that the wind effect can reach serious levels, especially in open areas and at high altitudes.

Geographical Location and Climate of İspir

İspir, one of the 20 districts of Erzurum, is located in the north of the city. Figure 3 shows a map of İspir and its neighborhoods. It borders the provinces of Rize and Artvin, and the districts of Tortum and Pazaryolu (Aktemur & Kukaracı, 2004). İspir and its surroundings consist of two basins: the Çermeli Stream Basin to the south (forming a small part of the Upper Çoruh Basin) and the Middle Çoruh Basin to the north. İspir, which has a mountainous terrain, is bordered by the Soğanlı-Kaçkar Mountains to the north and the Mescit Mountains to the south (Taşcı, 2008). İspir is located at an altitude of 1120 meters and has a surface area of 2244 km² (Çağlayan, 1981, p. 9).

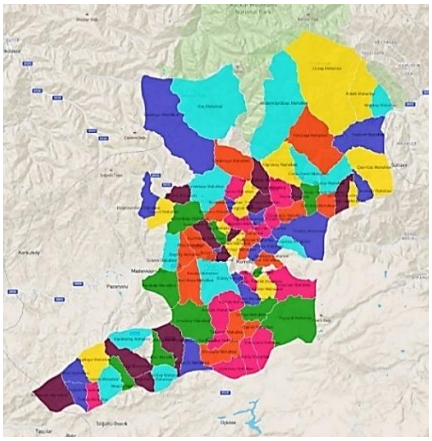


Fig. 3. Map showing the neighborhoods of İspir
Source: (atlasbig.com.tr)

The İspir district is close to the Black Sea region, but due to the Bahar Mountains in the north cutting off its connection to the sea, its climate does not exhibit the characteristics of the Black Sea climate. However, thanks to the mountains located south of the Çoruh Valley, it also does not fully reflect the harsh continental climate of Erzurum. İspir appears to have a transitional climate between the Black Sea and continental climates (Aktemur & Kukaracı, 2004).

The region derives its income from agriculture and animal husbandry. However, limited agricultural areas and insufficient livelihood resources cause the region to experience out-migration and a decrease in population over time (Taşcı, 2008). According to 2024 data, the region's population is 14,765. There are 7,468 men and 7,297 women in the region (Nufusu.com, 2026).

The history of the Çoruh valley, where İspir is located, dates back to the late 9th century BC. Over time, İspir has been home to many states and peoples, including the Hurrians, Urartians, Sakas (Scythians), Medes, Persians, Parthians and their successors; Romans, Byzantines, Sasanids, Arabs (the Four Caliphs period), Umayyads, Abbasids, Seljuks, Mongols-Ilkhanids, Kara Koyunlu, Timurids, Ak Koyunlu, the Georgian Kingdom, Ottomans, and the Republic of Turkey (Çağlayan, 1981).

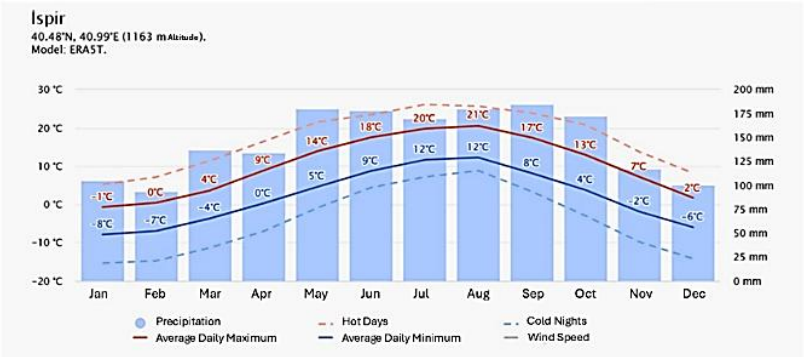


Fig. 4. Average temperature and precipitation graph for İspir
Source: (meteoblue.com)

According to Meteoblue (2026) data, the İspir district exhibits a distinctly continental climate for most of the year. As shown in the graph in Figure 4, average maximum temperatures in winter (December–February) are around or below 0°C, while minimum temperatures range between -6°C and -8°C. This indicates that temperatures remain low during winter and frost is frequent.

With the arrival of spring, temperatures show a rapid upward trend; a significant increase in both daytime and nighttime temperatures is observed, particularly from April onwards. During summer (June–August), average maximum temperatures rise to the 18–21°C range, making it the warmest period of the year. However, the fact that minimum temperatures remain at the 8–12°C level indicates that summer nights are relatively cool and daily temperature differences remain significant.

According to data from 1991-2021, the average relative humidity in İspir district was measured at 68% in June (Climate-Data.org, n.d.). Based on the same data, the average sunshine duration in the district in June was determined to be 9.1 hours. The total annual sunshine duration in İspir district was measured at approximately 2562.35 hours. According to data from the General Directorate of Meteorology for the years 2004-2021, the global solar radiation in İspir district is approximately in the range of 3.91–4.4 kWh/m²/day. Data for Petekli Village shows a range of 4.31-4.4 kWh/m²/day, while Güllübağ Neighborhood's global solar radiation value is in the range of 4.21-4.3.

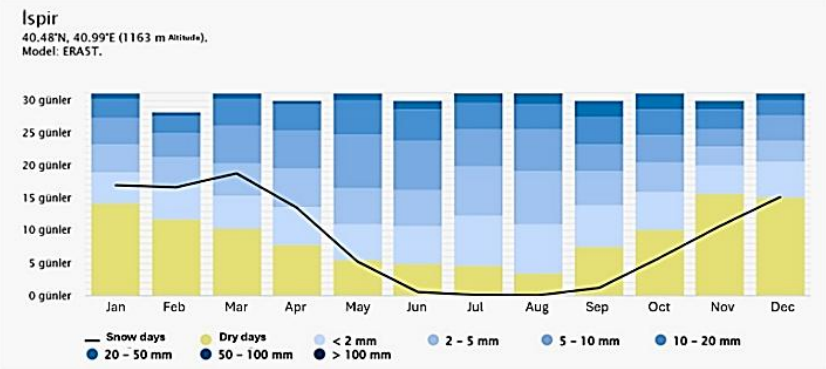


Fig. 5. Average rainfall graph for İspir
Source: (meteoblue.com)

Examining the precipitation data in the graph shown in Figure 5, it is understood that although the amount of precipitation is relatively low in winter, this precipitation largely occurs as snow. Precipitation increases significantly in the spring months (especially May) and reaches its highest levels of the year. In the summer months, the decrease in precipitation in the region results in a drier summer. In autumn, precipitation tends to increase again and continues at moderate levels towards the end of the year.

Petekli Village

Petekli Neighborhood, also referred to as Karsor in older sources (Nişanyan Yeradları, n.d.), was a village within the İspir district until 2012. Following the abolition of all village legal entities under Law No. 6360, it became a neighborhood within the İspir Municipality. Located southwest of İspir, the neighborhood is 15 km from the district center. Figure 6 shows a map of Petekli Village. According to 2024 data, the neighborhood's population was calculated as 120, consisting of 62 men and 58 women (nufusune.com, n.d.). Figure 7 shows a graph illustrating the change in Petekli Village's population over time.



Fig. 6. Map of Petekli Village
Source: (edited by the author, referencing parselsorgu.tkgm.gov.tr).

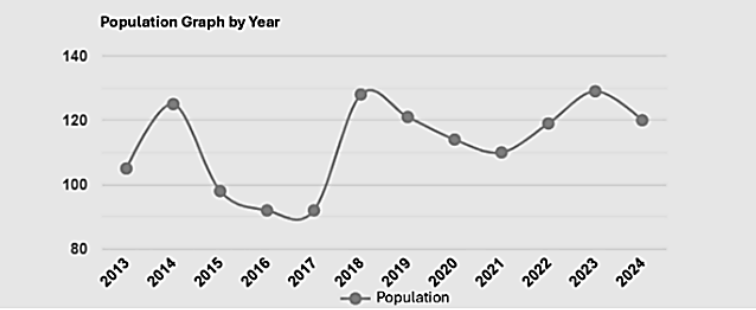


Fig. 7. Population graph of İspir Petekli Neighborhood by year
Source: (nufusune.com)

Güllübağ Neighborhood (Varkur Village)

The name of Güllübağ Neighborhood appears as Varkur, of Armenian origin, in the 1912 records, and as Varkor in the 1928 records (Nişanyan, 2026). The neighborhood is located 149 km from the center of Erzurum city and 5 km from the center of İspir district. Figure 8 shows a map of Varkur Village. The population of the neighborhood generally shows a decreasing trend between 2007 and 2025. Although a short-term increase was observed in 2018-2019, the population has stabilized at approximately 125-130 people in recent years. Figure 9 shows the graph of the change in the neighborhood population over the years.



Fig. 8. Satellite image of Güllübağ Neighborhood
Source: (Map taken from Google Maps, 2026, edited by the author)

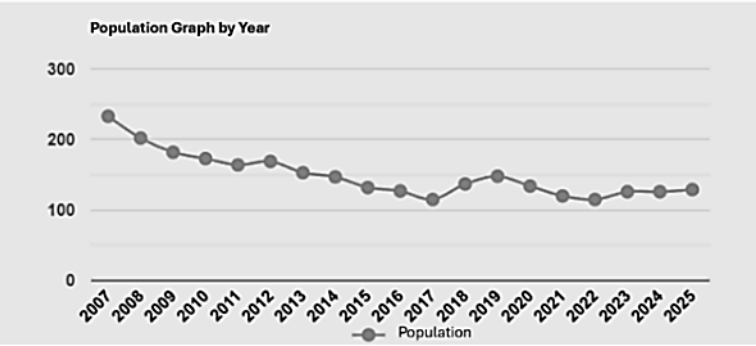


Fig. 9. Population graph of Güllübağ Neighborhood
Source: (nufusune.com)

Humidity Measurement Method and Equipment Used

During the study, a UniChrome brand digital thermometer-hygrometer was used to determine indoor temperature and relative humidity values. The device simultaneously measures and displays the ambient temperature (°C) and relative humidity (%RH) on a digital display. The digital thermometer-hygrometer used can measure ambient temperature between -50 °C and +70 °C with an accuracy of ±1 °C. The relative humidity measurement

range of the device is 10–99% RH, with an accuracy of ±5% RH and a resolution of 1% RH. A photograph of the device used is shown in Figure 10.



Fig. 10. Digital thermometer-hygrometer
Source: (Photo taken by the author)

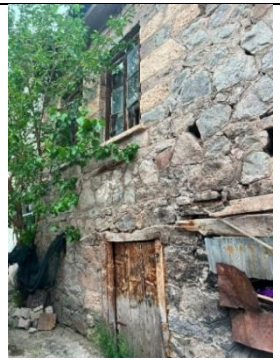
Structures Examined and Data Collection Process

The data collection process of the research consisted of on-site examinations, humidity and temperature measurements, photographic records, and observational evaluations carried out in traditional structures located in Petekli Village and Güllübağ Neighborhood. Six traditional structures with different physical characteristics and usage conditions were examined to conduct the field study. Figure 11 shows photographs of the buildings. The main criteria for selecting the structures to be examined were that the structure had preserved its architectural character, that moisture-related damage was observable on the structure, and that it was accessible within the scope of the research. In the data collection process, measurement points were determined in the interior and exterior spaces for each structure. In the selection of measurement points, the focus was on wall surfaces where moisture damage was observed intensively, areas close to ground level, areas on the facades exposed to rain and surface water, and spaces where ventilation conditions differed. At the determined points, ambient temperature and relative humidity values were measured and recorded.



Fig. 11. Photographs of the structures examined
Source: (Photo taken by the author)

Table 3. General characteristics and images of the structures examined

Apartment Number	Building Image	Construction System	Number of Floors	Identifiable Sources of Moisture	Observed Deterioration	Inspection Date	Materials Used
K1		This is an example of a traditional house with a stone-built lower floor and a wooden frame upper floor.	2	- Moisture rising from the ground (capillary rise) - Surface and rainwater - Moisture originating from the roof and eaves	- Plaster losses and peeling - Mortar and joint losses - Segregation on stone surfaces - Gaps and deformations in wood coverings - Surface soiling and discoloration - Biological formations	06.06.2026	Natural stone – predominantly volcanic stone (basalt type), cement-based and soil-based mortar, wooden cladding, corrugated galvanized metal/sheet metal.
Location		Building Orientation	Usage Status			Window Positions	Age of the building
Güllübağ Neighborhood		Southeast-Northwest	It is actively in use.			Northeast-1	70
K2		It is a traditional dwelling built using a stone masonry system.	2	- Moisture rising from the ground -Surface water / rain splash -Influence of moisture due to vegetation -Rainwater ingress through openings in the stone wall	- Moisture and discoloration in lower sections of the wall - Staining and darkening on stone surfaces - Mortar and joint losses - Abrasion and material loss on stone surfaces - Joints that are partially empty or hollowed out - Deformation, abrasion, discoloration, and material loss in wooden elements - Biological formations - Loss of integrity in stone masonry in some areas	06.06.2026	Irregular natural stone, lime-based mortar, galvanized steel sheet, minimally processed wood.
Location		Building Orientation	Usage Status			Window Positions	Age of the building
Güllübağ Neighborhood		Northeast-Southwest	It is actively in use.			Northeast-2	75
K3		The building was built with a traditional mixed masonry system consisting of rubble stone masonry on the ground floor and adobe masonry walls on the upper floor. Floor slabs and roof carriers consist of wooden elements.	3	- Increased humidity (capillary humidity) - Rainwater effect - Insufficient drainage and surface water - Humidity created by vegetation	- Material loss and erosion in adobe walls - Wall cracks and separations - Deterioration in wooden elements - Damage to the roof system - Joint losses - Biological formations - General wear and tear due to disuse and lack of maintenance - Surface deterioration due to moisture	06.06.2026	Natural stone, wooden frame, adobe infill, wooden roof supports, metal/sheet metal roofing, wooden doors.
Location		Building Orientation	Usage Status			Window Positions	Age of the building
Petekli Village		East-West	Abandoned.			East-2	80

Apartment Number	Building Image	Construction System	Number of Floors	Identifiable Sources of Moisture	Observed Deterioration	Inspection Date	Materials Used
K4		The structure is a traditional masonry building with a load-bearing system consisting of stone-built walls. The floor slabs and projection elements are made of wood, and the roof system has wooden supports and is covered with sheet metal.	3	- Moisture rising from the ground (capillary moisture) - Surface water and inadequate drainage - Effect of rainwater from roofs and eaves - Environmental humidity due to vegetation	- Joint loss in stone walls - Material loss and deterioration on stone surfaces - Horizontal cracks and openings - Deterioration in wooden balcony/projection elements - Biological deterioration - General wear and tear due to lack of maintenance	06.06.2026	Natural stone, mortar, wooden beams, wooden joinery, glass, metal railings, wooden roof supports, corrugated shee metal roof covering.
Location		Building Orientation	Usage Status			Window Positions	Age of the building
Petekli Village		East-West	Abandoned.			East-4 South-5 West-1	120
K5		The building was constructed using a traditional mixed-use technique, with rubble stone masonry on the ground floor and a timber frame and timber-infill half-timbered system on the upper floors.	3	- Rising humidity (capillary humidity) - Effect of rainwater from roofs and eaves - Water ingress through wooden facade elements - Environmental humidity due to vegetation - Moisture accumulation in wood-stone junction areas	- Deterioration and decay in wooden elements - Separation and deformation in wooden cladding - Joint losses in stone walls - Local material losses in stone walls - Deterioration at the stone-wood joint line - Surface deterioration due to moisture and atmospheric effects - Risk of biological deterioration	06.06.2026	Natural stone, adobe/eart fill, wood, thin wooden branches/slats, corrugate metal/sheet metal.
Location		Building Orientation	Usage Status			Window Positions	Age of the building
Petekli Village		East-West	It is actively in use. (Barn)			East-1 North-1	60
K6		The building was constructed using a traditional mixed-use technique, with stone masonry on the ground floor and a timber frame and timber-infilled half-timbered system on the upper floor. It exhibits the stone-wood mixed-structure characteristic commonly seen in Anatolian rural architecture.	3	- Rising humidity (capillary humidity) - Rainwater ingress from roof and facade - Lack of gutters and drainage - Surface water - Environmental humidity due to vegetation - Stone-wood junction areas	- Advanced deterioration in wooden elements - Loss and separation in facade cladding - Joint losses in stone walls - Surface erosion in stone walls - Deformation in stone-wood joints - Deterioration in the roof system - Risk of biological deterioration	06.06.2026	Adobe bricks, Natural stone masonry, Wooden posts, beams and lintels, Corrugated metal/sheet metal, PVC windows and doors + glass, Earth/adob based plaster.
Location		Building Orientation	Usage Status			Window Positions	Age of the building
Petekli Village		East-West	It is used seasonally.			East-1 North-1 West-1	50

Source: (Prepared by the author. Images used were taken by the author)

Table 3 lists the structures examined. These structures consist of examples of rural architecture using stone and adobe construction systems. The use of local materials is prominent in these buildings, and corrugated sheet metal roofing is used on stone, adobe, and wooden roofs.

While some buildings are still in active use, others are abandoned and derelict. In abandoned buildings or those not regularly used, various physical deteriorations have occurred due to irregular maintenance and repair, as well as the influence of environmental factors. The most frequently encountered deteriorations in the examined structures were: advanced deterioration in wooden elements, material loss and separation in facade cladding, joint loss in stone walls, erosion and material loss on stone surfaces, deterioration in roof systems, and biological deterioration due to vegetation.

It has been determined that the factors causing moisture formation in the building are capillary rising humidity, rainwater effect, inadequacies in the drainage system and environmental humidity due to biological formations. Wall bottoms that are in direct contact with the ground are more exposed to moisture due to capillary effect. In addition, rainwater contact with roofs and facades as a result of inadequate drainage systems is among the main reasons that cause moisture-related deterioration.

When the observations are evaluated holistically, the current buildings largely preserve their original architectural characteristics. Despite this, physical deterioration occurs in the buildings due to lack of periodic maintenance, lack of active use, and environmental factors caused by climate change and the harsh weather conditions of the region. It is necessary for the sustainability of the architectural heritage to register traditional structures that are considered documents, to establish regular maintenance programs and to develop appropriate conservation interventions for existing damages.

RESULTS AND DISCUSSION

On June 6, 2026, relative humidity measurements were taken in the buildings as part of the research. The measurement time was set as 13:00 to 14:00, and measurements were taken under the same time conditions for all buildings. During the research, the outside air temperature was measured between 23.5°C and 25°C, aiming to provide comparable environmental conditions for all case studies. According to data from June 6, 2026, the maximum relative humidity in Petekli Village was measured at 85% at 02:00. On the same date, the minimum relative humidity was measured at 44% at 13:00. Similarly, in Güllübağ Neighborhood, the maximum relative humidity was measured at 81% at 05:00, while the minimum relative humidity was measured at 42% at 13:00 (Buluttan.com, n.d.).The relative humidity measurement results reveal that the indoor humidity level is higher than the outdoor humidity level in all buildings. Numerical results show that outdoor relative humidity values ranged between 42% and 46%, while indoor values ranged between 48% and 67%.

The highest indoor humidity value (67%) was measured in the building currently used as an active barn. This high humidity level can be attributed to moisture from animal respiration, manure, and waste, as well as limited ventilation within the building. In contrast, indoor humidity values in residential buildings ranged between 48% and 58%. In light of this data, Table 4 was created by the author to evaluate the moisture-induced deterioration observed in the structures, and the signs of deterioration found in the structures are presented in list form.

The fact that indoor relative humidity values were higher than outdoor humidity values in all structures can be attributed to the physical characteristics of the structures as well as the seasonal conditions under which the measurements were taken. Since the measurements were taken in June, during the warmest time of day between 13:00 and 14:00, the outdoor temperature was higher, and consequently, the outdoor relative humidity levels were measured at relatively low levels. In contrast, traditional building materials such as stone and adobe can store a certain amount of moisture and maintain this moisture by reacting more slowly to changes in outdoor conditions. Furthermore, limited ventilation conditions in the spaces can cause the humidity inside the structure to be higher than the outdoor level. Therefore, it can be said that the difference between indoor and outdoor humidity values is not only due to the structure itself, but also related to the seasonal and daily climatic conditions of the period in which the measurements were taken.

During field investigations, it was observed that buildings with high humidity levels generally suffered more pronounced deterioration, such as surface erosion, mortar loss, cracking, material disintegration, deformation of wooden elements, and layer separation. The findings indicate that humidity plays a significant role in the deterioration processes of traditional stone and adobe structures by affecting the physical performance of building materials. In structures with high indoor humidity, darkening of wooden elements, surface deformations, and material loss were observed to be more pronounced.

When the relationship between the usage status of the structures and humidity values was evaluated, it was determined that, with the exception of the barn, the examined structures that were not actively used had relatively

high indoor humidity values. Depending on the indoor humidity value, mold and mildew formation, damp-induced odor formation, and damp-induced staining were more frequently observed in these structures. In structures that are not regularly ventilated and adequately maintained due to inactive use, the retention of moisture within the structure for a long time is among the main reasons for the occurrence of biological formations.

In the examined traditional structures, moisture formation is among the primary factors in material deterioration. The effect of moisture on building materials increases or decreases depending on the building's location, usage, ventilation conditions, and whether or not periodic maintenance is performed. Changes in temperature, humidity, and precipitation regimes due to climate change are also among the factors that accelerate deterioration. While conducting conservation efforts based on the findings of inspections, in addition to identifying and neutralizing moisture sources, the building's usage and environmental conditions should also be considered in terms of the persistence of damage. Preparing climate change-adaptive emergency action plans is crucial for the preservation and continued existence of these structures.

Table 4. Deterioration Due to Moisture in Traditional Buildings - Detection Table

The most common signs of visible and latent moisture damage	K1	K2	K3	K4	K5	K6
	Outdoor Humidity	Outdoor Humidity	Outdoor Humidity	Outdoor Humidity	Outdoor Humidity	Outdoor Humidity
	% 42	% 43	% 46	% 43	% 44	% 44
	Indoor Humidity	Indoor Humidity	Indoor Humidity	Indoor Humidity	Indoor Humidity	Indoor Humidity
	% 51	% 50	% 58	% 57	% 67	% 48
Presence of stagnant water, mold, mildew, or dampness	+	-	+	+	+	-
Wet stains, worn surfaces, or salt deposits on interior and exterior surfaces.	+	+	+	+	+	+
Peeling paint and plaster, peeling wallpaper, or moisture bubbles on finished surfaces	+	-	+	-	+	Partially
Musty, musty odors in areas with high humidity or poor ventilation.	+	+	+	+	+	-
Rust and corrosion stains on metal elements such as roof anchoring systems and protruding roof studs	+	+	+	+	+	+
Borrowed, warped, cracked, or rotten wood	+	+	+	+	+	+
Crumbling, cracked masonry or worn mortar joints	+	+	+	+	+	+
Defective roofs and gutters, including missing roofing slates, tiles or shingles, and roofing or gutters in poor condition.	+	+	+	Partially	+	+
Condensation on window and wall surfaces	-	-	-	-	-	-
Water accumulation around the building due to inadequate drainage.	-	-	-	-	-	-
Discoloration that appears as darkening or discoloration on surfaces.	+	+	Partially	Partially	+	+
The formation of undulations, bending, or irregular shape changes on surfaces.	-	+	+	+	+	+
The material loses its integrity and breaks off into small or large pieces.	+	+	+	+	+	+
The surface of the material thins over time and loses its original texture.	+	+	+	+	+	+
Cracks occur due to expansion and contraction caused by changes in humidity.	Partially	+	+	+	+	+
Delamination disorders seen with surface blistering, separation, and flaking.	+	+	+	Partially	Partially	+
The formation of white, crystalline or crusty deposits on the surface as a result of water evaporation (Salt efflorescence, Efflorescence)	-	-	-	-	-	-

Source: (Prepared by the Author) (While determining the evaluation criteria, the following sources were used: (Park, 1996), (Eroğlu and Halaç, 2022) and (Ünlü, 2025)

Note: In Table 4, the **'+'** sign indicates that the most common signs of visible and latent moisture damage were observed in the structure, the **'-'** sign indicates that they were not observed, and **'partially'** indicates that they were partially present.

CONCLUSION

Moisture is among the main factors affecting the deterioration of traditional structures. However, the observed damage cannot be explained solely by existing moisture levels. Usage conditions, maintenance conditions,

environmental and climatic factors, climate change, and long-term natural weathering processes also play a role in the formation and progression of deterioration. Therefore, in conservation applications related to moisture deterioration, broader conservation proposals should be prepared that take into account both environmental and building-specific factors. As a result of observations made during the field study and literature review, when applying preventive conservation strategies, the correct identification and elimination of moisture sources causing damage should be prioritized. When identifying the moisture source, indicators of deterioration such as damp surfaces, biological formations, mortar losses, deformations in wooden elements, salt accumulations, surface discoloration, and cracks should be carefully monitored. These signs indicate the early stages of moisture-related damage. Timely detection of these signs prevents the progression of deterioration and minimizes the need for extensive restoration interventions.

Effective moisture management practices in buildings require regular monitoring of rainwater, groundwater, and internal moisture sources. Regular inspection and maintenance of roofs, drainage systems, gutters, wall surfaces, and openings are necessary to prevent water seepage and moisture accumulation. In addition, improving natural ventilation, preventing building abandonment, controlling indoor humidity levels, and preventing biological growth contribute to limiting the occurrence of deterioration.

Damage assessments in buildings highlight the importance of periodic monitoring and maintenance programs. Conservation and restoration interventions should not be limited to corrective actions after deterioration has occurred. Furthermore, preventive maintenance practices, regular inspections, and continuous environmental monitoring should be integrated into long-term conservation strategies. These approaches are particularly important for rural architecture, which has faced threats of limited maintenance and abandonment in recent years.

In this study, moisture measurements were carried out under similar climatic conditions and within a limited time frame. Therefore, a snapshot of the buildings' performance under environmental influences was obtained. Since moisture values can vary depending on seasonal changes, weather conditions, usage patterns, and ventilation regimes, the results obtained should be interpreted carefully. Future studies should include long-term monitoring programs with repeated measurements in different seasons and climatic conditions to gain a more comprehensive understanding of moisture behavior and its relationship to material degradation. Such research will provide a stronger foundation for developing conservation strategies and improving the environmental performance of conventional buildings.

DECLARATIONS

Declaration of AI Use

During the preparation of this article, the author used the ChatGPT (OpenAI) tool to obtain suggestions for making the text linguistically clearer, more fluent, and more understandable, as well as to assist in the interpretation of climate data. The suggestions provided by the artificial intelligence tool were evaluated by the author, and the author implemented the revisions deemed appropriate. The scientific content, analyses, evaluations, and conclusions of this article were not generated by artificial intelligence; the final content of the study and scientific responsibility rest entirely with the author.

Author Contributions

Mesude Zor: Conceptualization, Methodology, Research, Data Collection and Organization, Formal Analysis, Drafting the Original Manuscript, Visualization.
Asena Soyluk: Conceptualization, Guidance and Supervision, Review and Editing.

All authors have read and approved the final version of the article to be published.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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