Year XVIII, vol. 61, no. 3, 2025, p.1542-1552
DOI 10.30892/gtg.61313-1523

SPATIAL-TEMPORAL ANALYSIS OF THE DISTRIBUTION PATTERNS OF GREIG'S TULIP (LAT. TULIPA GREIGII) IN THE LANDSCAPES OF TURKISTAN REGION AND OPPORTUNITIES FOR ECOTOURISM DEVELOPMENT

Dana AKHMETOVA [1*], Alexander N. DUNETS [2]

[1] L.N. Gumilyev Eurasian National University, Departament of Physical and Economical Geography, Astana, Kazakhstan; akhmetovadanaaa@mail.ru (D.A.)
[2] Altai State University, Department of Scientific and Innovative Development, Barnaul, Russia; dunets@mail.ru (A.N.D.)

Citation: Akhmetova, D., & Dunets, A.N. (2025). Spatial-temporal analysis of the distribution patterns of greig's tulip (lat. tulipa greigii) in the landscapes of Turkistan region and opportunities for ecotourism development. *Geojournal of Tourism and Geosites*, 61(3), 1542–1552. https://doi.org/10.30892/gtg.61313-1523

Abstract: The present study investigates the spatial-temporal patterns of Tulipa greigii distribution across the heterogeneous landscapes of the Turkistan Region, southern Kazakhstan. As a flagship species with high conservation and ecotourism value Tulipa greigii is increasingly affected by climate variability and landscape fragmentation. The aim of the research is to identify the ecological parameters governing tulip distribution and to assess the potential for sustainable ecotourism based on floral landscape dynamics. The methodology integrates field ecological surveys, multi-seasonal remote sensing (Sentinel-2 and Landsat 8), and geospatial modeling using NDVI and NDMI indices. Additionally, public interest and ecotourism potential were assessed through digital footprint analysis on social media platforms (Instagram and TikTok), as well as national visitation statistics. Geostatistical tools were employed to analyze spatial trends and vegetation stress patterns across six key study locations selected for their landscape diversity. Findings reveal a strong correlation between seasonal soil moisture levels and the spatial presence of Tulipa greigii. Higher vegetation indices were observed in slope-adjacent piedmonts and montane meadow belts, which also correspond with increased social media activity during the blooming season. The results confirm the role of geomorphological position, hydrological balance, and digital visibility in determining ecotourism hotspots. This study demonstrates the value of interdisciplinary methods in understanding plant distribution and promoting nature-based tourism. By integrating biophysical indicators with geospatial technologies and public engagement metrics, the research provides a holistic framework for identifying ecologically significant zones under pressure from climate change and human activity. Moreover, the proposed approach highlights the utility of coupling traditional ecological monitoring with digital analytics to track spatial interest trends and ecological vulnerabilities. The study contributes to the scientific basis for the development of adaptive conservation strategies, fostering synergies between biodiversity protection and regional ecotourism planning. It provides regionally grounded and practically oriented recommendations for harmonizing biodiversity conservation efforts with the development of digital ecotourism strategies, tailored specifically to the ecological and socio-spatial characteristics of Central Asia's dryland landscapes.

Keywords: Tulipa greigii, spatiotemporal analysis, NDVI, NDMI, Turkistan Region, ecotourism, social media

* * * * * *

INTRODUCTION

Tulips are perennial geophytic plants belonging to the family *Liliaceae*, notable not only for their contribution to biological diversity but also for their significant economic, horticultural, ecological, and aesthetic value (Pavord, 1999). Central Asia, particularly Kazakhstan, is considered the primary genetic center of origin for tulips (Vvedensky & Kovalevskaya, 1971; Hoog, 1973). Scientific research on tulips began in the late 18th century, with P.S. Pallas being the first to describe species in Western Siberia and adjacent regions. In the 19th century, prominent botanists such as A. Lehman, I. Kirilov, I. Borshchow, L. Shrenk, S. Karelin, and E.A. von Regel made significant contributions to the classification of *Tulip* taxa in the flora of Kazakhstan. *Tulipa greigii* was first described in 1873 by the botanist E.L. Regel. It was studied based on herbarium materials collected by A. Severtsev and B. Fedchenko in the Karatau Mountains.

Initially, this tulip was identified as a variety of a specific species under the name *Tulipa altaica var. karatavica* Regel. is found in the Karatau mountain range of southern Kazakhstan. However, later that same year, Regel recognized it as a distinct species (Ivashchenko & Belyalov, 2019; Tojibaev et al., 2022). As research progressed, numerous studies were published on the morphology, genetics, ecology, and distribution of tulips. *Tulipa greigii* is an endemic and rare species found in the southern and southwestern regions of Kazakhstan, including the Turkistan Region, Karatau Range, Kyzylkum Desert, Betpak-Dala Plateau, and up to elevations of 2400 meters in the Tian Shan mountain system. It typically grows on clay and rocky slopes, as well as in foothill plains and mountain flukes. This bulbous perennial of the *Liliaceae* family reaches a height of 10–30 cm. Its flowers are bright red, orange, or yellow, often with a black or purple center.

* Corresponding author

According to its phenology, *Tulipa greigii* flowers between April and June and produces fruit from June to July. The species primarily reproduces vegetatively through bulbs, while seed propagation is relatively rare. It typically grows in dry, gravelly, semi-desert, and mountainous regions. Due to its limited population and distribution, the species is listed in the Red Book of Kazakhstan. As part of conservation measures, *Tulipa greigii* is protected within the boundaries of the Sairam-Ugam National Park, Aksu-Zhabagly Nature Reserve, and Karatau State Nature Reserve. Additionally, ex-situ conservation and propagation programs are being considered to support the preservation of natural populations (Kubentayev et al., 2024). The risk of extinction for *Tulipa greigii* is associated with its narrow geographic range and increasing anthropogenic pressures. Major threats include the expansion of agriculture (e.g., increasing cultivated areas, use of fertilizers), overgrazing (leading to habitat degradation), urbanization (land development, construction of roads and infrastructure), climate change (droughts, decreased precipitation), and illegal harvesting for commercial purposes.

The expansion of agricultural activities, pastures, and urban infrastructure, along with climate variability, are negatively impacting the species' population. Moreover, the illegal collection and commercialization of tulips significantly contribute to their population decline in the wild (Christenhusz et al., 2013). *Tulipa greigii* is one of the key species that enhances the aesthetic and ecological value of natural landscapes. The development of ecotourism is considered an effective strategy for conserving its natural populations, as adherence to environmental regulations contributes to the protection of the species' natural habitat. Furthermore, ecotourism supports local economies and creates sustainable income opportunities while fostering a culture of environmental awareness and nature conservation within communities.

In this study, photogeographical mapping and GIS technologies were employed to conduct spatial analysis. The study area was mapped, and satellite imagery was interpreted. Scientific analyses were carried out to identify the distribution patterns of *Tulipa greigii*, evaluate the impact of anthropogenic factors on its spatial differentiation, and assess the potential of conserving the species through ecotourism development. Areas of *Tulipa greigii* distribution, main highways, hotels, and other tourist-related infrastructure were identified. Additionally, to assess public interest in the distribution and ecotourism potential of *Tulipa greigii*, statistical data from social media platforms were analyzed. The data collection and processing involved analyzing trending hashtags, geolocation information from users, and the frequency of related posts.

The primary aim of this study is to determine the spatial distribution patterns of *Tulipa greigii* within the diverse landscape structures of the Turkistan Region, critically evaluate the anthropogenic drivers influencing its population dynamics—including land degradation, agricultural transformation, and tourism-induced pressures—and to formulate a scientifically grounded strategy for the sustainable development of ecotourism based on species conservation priorities.

To achieve this aim, the following research objectives have been established:

To delineate the current distribution range of *Tulipa greigii* across the landscapes of the Turkistan Region using field data and remote sensing tools;

To assess the spatiotemporal dynamics of its habitat and quantify the extent of anthropogenic impacts, including land-use change, grazing pressure, and infrastructural development;

To evaluate the ecotourism development potential of *Tulipa greigii* by identifying its ecological and aesthetic value, with a particular emphasis on opportunities for seasonal and conservation-based tourism.

In recent years, the number of scientific studies focused on the spatial distribution and ecotourism potential of *Tulipa greigii* and related species has increased. However, the thematic scope and methodologies employed in these studies remain limited, particularly in terms of spatial-temporal modeling, quantitative assessment of anthropogenic impacts, and the integration of socio-ecological linkages. For instance, the work of Kubentayev et al. (2024) prioritizes the floristic and taxonomic classification of *Tulipa* species and provides cartographic representations of their distribution across Kazakhstan. Nevertheless, it does not address the spatial-temporal dynamics of population trends or the influence of anthropogenic pressures. Sutula et al. (2024) describe the genetic diversity and phylogenetic structure of rare Tulipa species. However, their findings are not linked to specific landscape conditions or the ecological status of habitats, which limits the applied value of the research. Although Debnath et al. (2023) successfully model land cover transformation using spatial techniques, their study is not related to the distribution of rare or endemic plant species, nor does it explore the interconnections between biodiversity and tourism. To address this gap, the present study conducts a species-specific ecological assessment utilizing Sentinel-2 and Landsat 8 satellite data along with NDVI and NDMI indices.

Eker et al. (2024) analyze the relationship between soil and vegetation but fail to sufficiently consider ecosystem stress factors, recreational load, or field-based observations.

From the perspective of information and communication approaches, Ionescu et al. (2016) underscore the role of ecotourism mapping in promoting protected areas. However, the study does not incorporate data reflecting public interest and tourism activity from modern digital platforms, such as hashtags and geotagged information on social media. This gap is addressed in the current research through the integration of data obtained from TikTok and Instagram platforms.

Overall, previous studies reveal several methodological limitations, including:

-limited availability or low spatial resolution of geospatial data;

-insufficient analysis of the relationship between species distribution and landscape structure;

-lack of evaluation of social demand related to ecotourism;

-inadequate quantitative or qualitative characterization of anthropogenic factors.

To overcome these constraints, this study adopts an integrated methodological framework that combines ecological, geospatial, and digital data. Such an approach enables a comprehensive assessment of the factors influencing the distribution of *Tulipa greigii* populations and provides scientifically grounded recommendations for the conservation of natural habitats and the sustainable development of ecotourism.

MATERIALS AND METHODS

The object of this study is the Turkistan Region, located in the mid-latitudes of Central Eurasia. The region encompasses the eastern part of the Turan Lowland and the western ridges of the Tien Shan Mountains. Its total area is approximately 117,300 km², covering a vast territory in southern Kazakhstan. Turkistan Region borders Ulytau Region to the north, Kyzylorda Region to the west, Zhambyl Region to the east, and the Republic of Uzbekistan to the south. The study area is characterized by a complex terrain formed through various geological and geomorphological processes. The region's natural features are distinguished by diverse landscapes, including lowland plains, plateaus, mountain systems, and sandy deserts. The vegetation cover is divided into desert, semi-desert, steppe, and mountainous zones (Akhmetova et al., 2024).

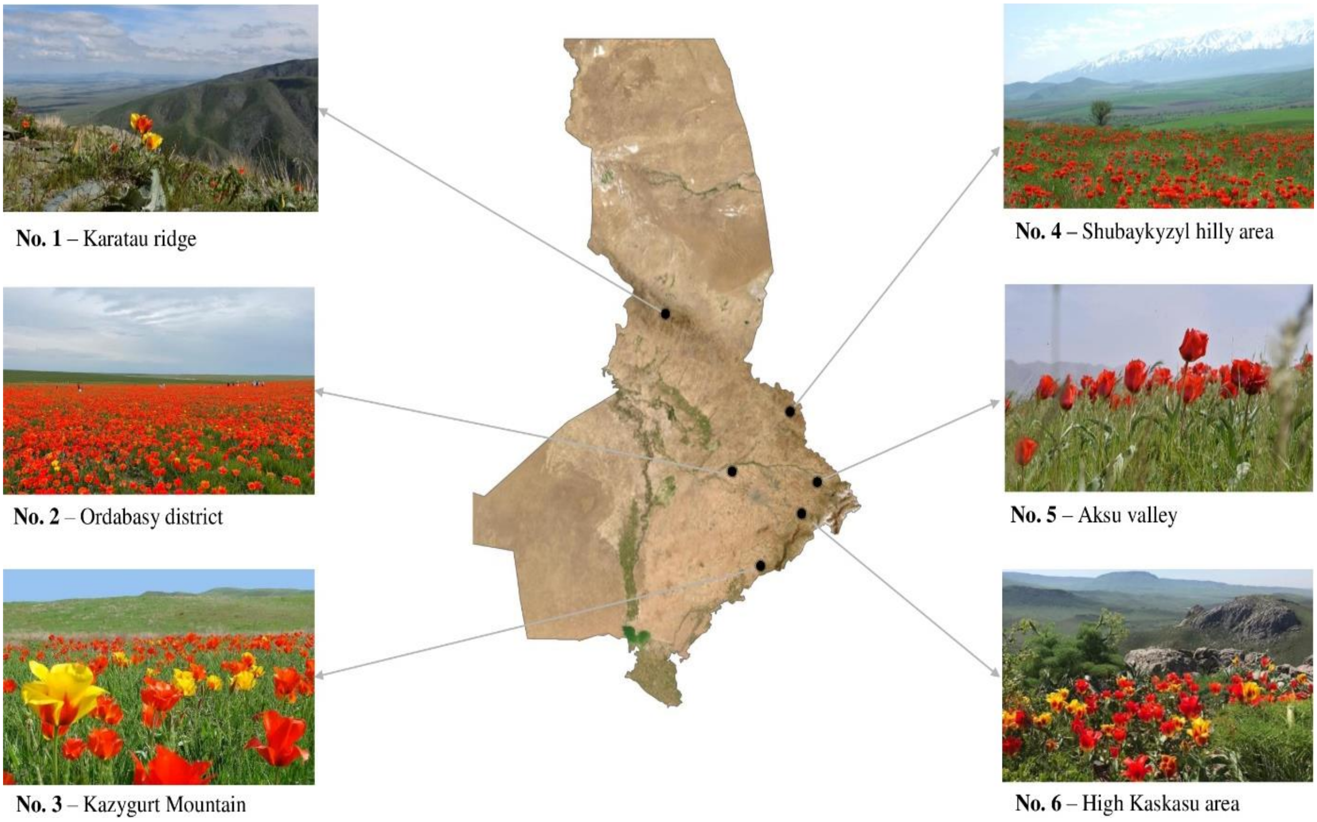

Figure 1. Photogeographical map of the study sites in the Turkistan Region (Source: Basemap imagery from Esri, Maxar, Earthstar Geographics (ArcGIS Online, 2025); photographs from the author's field archive (April 2024)

In order to comprehensively assess the distribution of *Tulipa greigii* and evaluate the ecological condition and value of the region's natural landscapes, six primary research sites (No. 1–6) were identified (Figure 1, Table 1).

Table 1. Main research directions in the Turkistan Region (Source: Author's fieldwork observations (April 2024) and analytical interpretation based on previously published data (Akhmetova et al., 2024)

Study Area	Coordinates	Elevation	Landscape Type	Types of Anthropogenic Activities	Total Projective Cover of *Tulipa greigii*, %
Karatau Range, Karatau State Nature Reserve	43°50'50"N 68°30'08"E	1488 m	Steppe mid-mountains	Increased recreational pressure	20–25%
Ordabasy District, Bank of Arys River	42°29'47"N 69°23'26"E	366 m	Desert plains	Anthropogenic erosion, expansion of road infrastructure, intensified agro-landscape transformation	60–70%
Kazygurt Mountain, Kazygurt District	41°49'11"N 69°42'07"E	1145 m	Semi-desert low mountains	Degradational pasture use, soil cover disturbance	40–50%
Shubaykyzyl Highland Area, Tulkibas District	42°42'54"N 70°03'41"E	964 m	Forest-steppe low mountains	Intensive grazing pressure, agricultural land development	70–80%
Aksu Valley, Aksu-Zhabagly State Nature Reserve (SNR), Turkistan Region	42°20'03"N 70°15'41"E	1371 m	Forested mid-mountains	Increased recreational pressure	50–60%
Upper Kaskasu Area, Sairam-Ugam State National Nature Park (SNNP)	42°14'22"N 70°00'48"E	1045 m	Semi-desert hilly uplands	Development of tourist infrastructure, accumulation of household waste, pasture degradation	30–40%

During the research, various sources were utilized, including literature reviews, thematic and physical-geographical maps, a 1:500,000 scale topographic map of the Turkistan Region, statistical data, remote sensing datasets, scientific research findings, and Maxar satellite imagery from 2024.

The study aimed to determine the distribution of *Tulipa greigii* using spatiotemporal monitoring methods and Geographic Information Systems (GIS), to analyze anthropogenic factors affecting its spatial differentiation, and to scientifically evaluate the potential for conserving the species through ecotourism development.

Field methods included floristic description, photogeographical mapping, sampling, and soil analysis. Floristic analysis was used to identify the flora of the study area, determine the distribution range of plant species, and estimate population density. Photogeographical mapping illustrated the geographical location and spatial distribution of plant species based on photographs and geographic data. The distribution areas of *Tulipa greigii*, as well as nearby roads, hotels, and other elements of tourism infrastructure, were identified. Using GIS, the spatial distribution of *Tulipa greigii* and the influence of ecological and anthropogenic factors were assessed. Sentinel-2 and Landsat 8 satellite data were used to map the distribution of the species. Direct assessment of *Tulipa greigii* population conditions is methodologically limited due to seasonal changes, climatic factors, and anthropogenic influences. Therefore, indirect evaluation of its habitat was conducted using the Normalized Difference Vegetation Index (NDVI), which quantifies the level of photosynthetic activity and biomass development in vegetation. This index served as a basis for assessing the suitability of ecological conditions within the distribution area of *Tulipa greigii* (Pettorelli et al., 2005). The Normalized Difference Vegetation Index (NDVI) is a key indicator used to assess the photosynthetic activity of vegetation.

The calculation of NDVI is based on the difference in reflectance between the near-infrared (NIR) and red (RED) spectral bands. The index is computed using the following formula (1) (Liu et al., 2015):

$$NDVI = \frac{NIR-RED}{NIR+RED} \qquad (1)$$

Where: NDVI – Normalized Difference Vegetation Index; NIR – Reflectance in the near-infrared spectral region;

RED – Reflectance in the red spectral region. This ratio allows for the assessment of the photosynthetic activity of vegetation cover. The NDVI values range from -1 to 1 and are influenced by vegetation density and growth intensity.

NDVI interpretation: 0.6 < NDVI ≤ 1.0 – Very dense vegetation cover, high photosynthetic activity;

0.2 < NDVI ≤ 0.6 – Moderate vegetation cover, normal photosynthetic activity; 0.0 < NDVI ≤ 0.2 – Sparse vegetation;

-0.1 < NDVI ≤ 0.0 – Bare surfaces (e.g., sand, rock, asphalt); NDVI ≤ -0.1 – Water bodies or ice cover

The NDMI (Normalized Difference Moisture Index) was used to assess vegetation moisture content. The spatiotemporal variations of these indices served as key indicators in characterizing the moisture conditions within the distribution range of *Tulipa greigii*. NDMI is an important index for evaluating vegetation moisture and water stress. It quantifies the water content in vegetation and soil based on satellite multispectral data and reflects the hydration state of plant cover. NDMI is calculated using reflectance values from the near-infrared (NIR) and shortwave infrared (SWIR) spectral bands. The formula for NDMI is given as follows (2) (Lykhovyd & Sharii, 2024):

$$NDMI = \frac{NIR-SWIR}{NIR+SWIR} \qquad (2)$$

NDMI – Normalized Difference Moisture Index; NIR – Reflectance in the near-infrared spectral region;

SWIR – Reflectance in the shortwave infrared spectral region.

NDMI values range between -1 and 1 and allow for the evaluation of vegetation moisture levels.

NDMI interpretation: NDMI ≤ -0.8 – Extremely dry soil areas, bare land with no vegetation

-0.8 < NDMI ≤ -0.4 – Areas with sparse vegetation or desert regions

-0.4 < NDMI ≤ 0.0 – Vegetated areas with high water stress

0.0 < NDMI ≤ 0.4 – Normal vegetation cover with low to moderate water stress

0.4 < NDMI ≤ 1.0 – Healthy vegetation cover, no water stress or areas with excess moisture

The NDMI index is widely used in agriculture, water resource management, drought monitoring, and natural ecosystem observation. It enables long-term assessment of vegetation moisture conditions and supports the forecasting of ecological changes. Currently, ecotourism is considered one of the key tools for ensuring nature conservation and sustainable development. In this context, statistical data on domestic tourism (residents) and inbound tourism (non-residents) were analyzed. To refine the findings, the ecotourism potential of *Tulipa greigii* was assessed through the analysis of social media data. A systematic analysis of information from TikTok and Instagram revealed the dynamics of public interest in *Tulipa greigii*, its position in the information space, and its role in ecotourism development.

During the study, statistical data on domestic and inbound tourism were obtained from the official website of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. These data were subjected to dynamic analysis. Additionally, structured data from social media platforms were collected and analyzed using tools such as Tweepy, Instaloader, and TikTokApi.

– A quantitative-statistical analysis of hashtag indicators was conducted.

– Data related to frequently used hashtags, views, and likes associated with *Tulipa greigii* on TikTok and Instagram were compiled. The spatial distribution and level of informational coverage of these indicators were assessed to characterize the tulip's popularity and position within the digital information ecosystem. Spatial-analytical mapping of geographic data – Based on geolocation data from social media posts, areas of ecotouristic appeal related to *Tulipa greigii* were mapped. This allowed for the identification of regional features of public interest in native flora and helped determine potential directions for the development of ecotourism. The results of the analysis laid the foundation for a comprehensive assessment of the ecological and touristic value of *Tulipa greigii*, provided insights into the dynamics of its popularity in society, and supported the development of sustainable ecotourism strategies with consideration of regional landscape characteristics. These findings contribute to the systematization of nature conservation efforts aimed at preserving the bioecological significance of tulips and inform the development of a scientifically grounded ecotourism concept.

RESULTS AND DISCUSSION

Tulipa greigii is distributed across the foothills and low-mountain areas of the Turkistan Region, particularly along the base of the Western Tien Shan and Karatau Ranges (Akhmetova et al., 2024) (Figure 2).

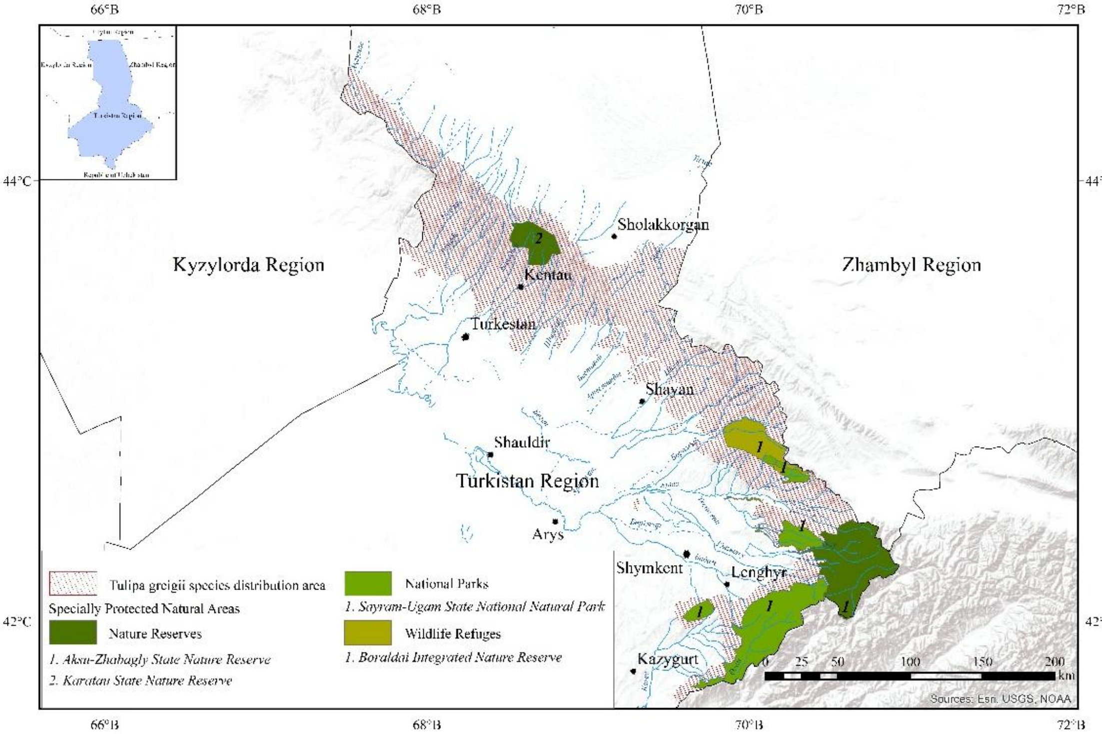

Figure 2. Distribution map of Tulipa greigii in the Turkistan Region (Source: Basemap imagery from Esri, USGS, and NOAA (2024); map compiled by the author using field data and spatial analysis in ArcGIS (April 2025)

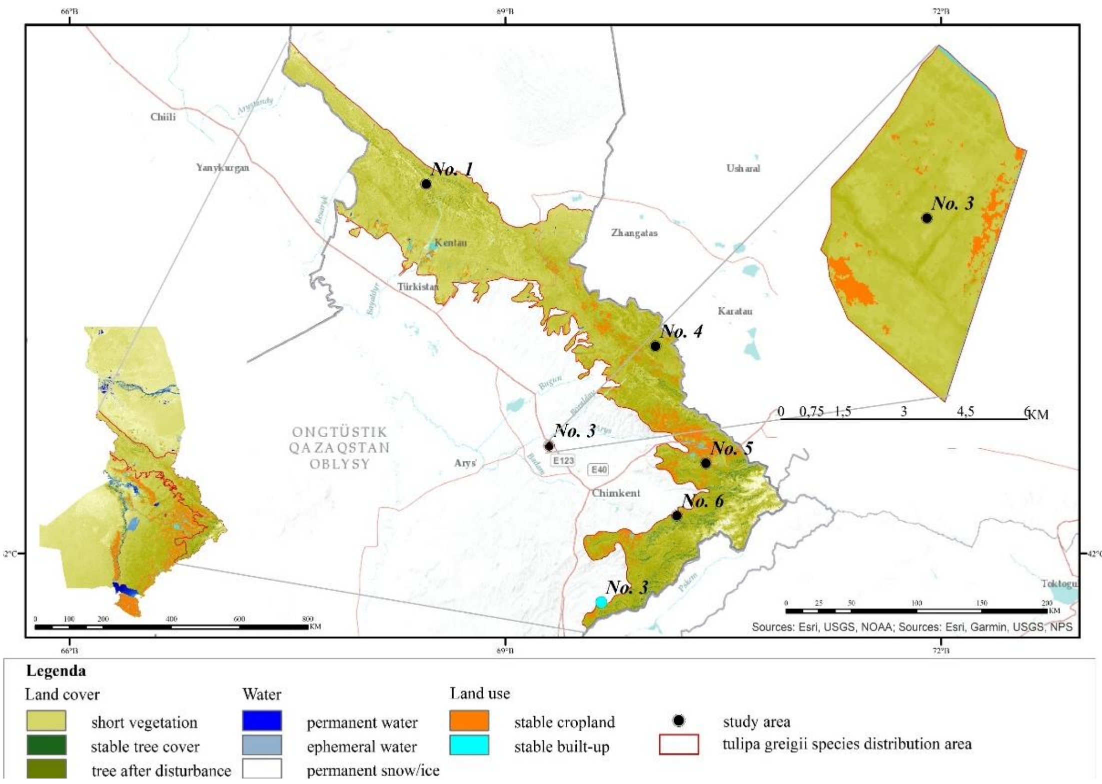

Figure 3. Land Use and Land Cover (LULC) classification map within the distribution area of Tulipa greigii in the landscapes of the Turkistan Region (Source: Basemap imagery derived from the GLAD Global Land Cover and Land Use Change dataset. The map was compiled by the author through spatial analysis using ArcGIS software (April 2025). Additional basemap imagery was obtained from Esri, USGS, and NOAA (2024)

Based on our field research, the distribution range of the species includes the Ordabasy District (along the Arys River), the Upper Kaskasu area (Sairam-Ugam State National Nature Park), the Karatau Range (Karatau State Nature Reserve), the Shubaykyzyl Highland area (Tulkibas District), and the Aksu Valley (Aksu-Zhabagly State Nature Reserve). In these locations, populations of *Tulipa greigii* were recorded, and detailed data were collected on their precise coordinates, elevation, slope exposure, landforms, soil types, and vegetation cover characteristics. The findings confirmed that *Tulipa greigii* predominantly occurs in mountainous landscapes (Kubentayev et al., 2024; Sutula et al., 2024).

The mountainous regions of the Turkistan Region are characterized by a diverse soil cover, including mountain gray-brown, meadow-gray, chestnut, gray-chestnut, and slightly humified brown soils. These soil types directly influence the distribution of *Tulipa greigii*, as they affect moisture retention, nutrient availability, and granulometric composition—factors essential for the species' growth and survival (Eker et al., 2024). The study results describe the spatiotemporal distribution patterns of *Tulipa greigii* and provide both quantitative and qualitative assessments of the ecological and anthropogenic factors influencing its population dynamics. Evaluation of the spatial dynamics of tulip populations revealed a heterogeneous distribution pattern, depending on various ecological gradients. Using global land cover and land use change data from the Landsat archive, the transformation of landscape structure in the Turkistan Region and its impact on the distribution of *Tulipa greigii* were analyzed (Figure 3) (Debnath et al., 2023).

Land cover was classified into categories such as short vegetation, persistent tree cover, post-disturbance trees, seasonal water bodies, permanent snow/ice, permanent water, croplands, and built-up areas (Orlikowska et al., 2018).

Increased anthropogenic pressure has led to habitat loss, reduced population density, and limited ecological plasticity of the species (Berdenov et al., 2015). Specifically, land cultivation, grazing pressure, and infrastructure development reduce the regenerative potential of *Tulipa greigii* and intensify habitat fragmentation across its distribution range.

The study comprehensively analyzed the spatiotemporal distribution patterns of *Tulipa greigii*, along with variations in the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Moisture Index (NDMI), which characterize the condition of vegetation cover within its habitat (Figures 4 and 5).

Direct assessment of the population status of *Tulipa greigii* presents certain methodological challenges, as its distribution dynamics are highly dependent on seasonal changes, climatic conditions, and anthropogenic influences. In this regard, an indirect assessment of the species' ecological condition was conducted by evaluating the vegetation activity in its habitat using the NDVI index. This index quantifies the photosynthetic activity and biomass development of vegetation, thereby enabling the evaluation of ecological suitability within the distribution range of *Tulipa greigii.* Additionally, analysis of the NDMI index enables the evaluation of ecosystem stability by determining the moisture levels of vegetation cover. A comprehensive spatiotemporal analysis of NDVI and NDMI dynamics provides a basis for identifying the ecological requirements of T. greigii, clarifying its distribution characteristics, and assessing the influence of environmental factors.

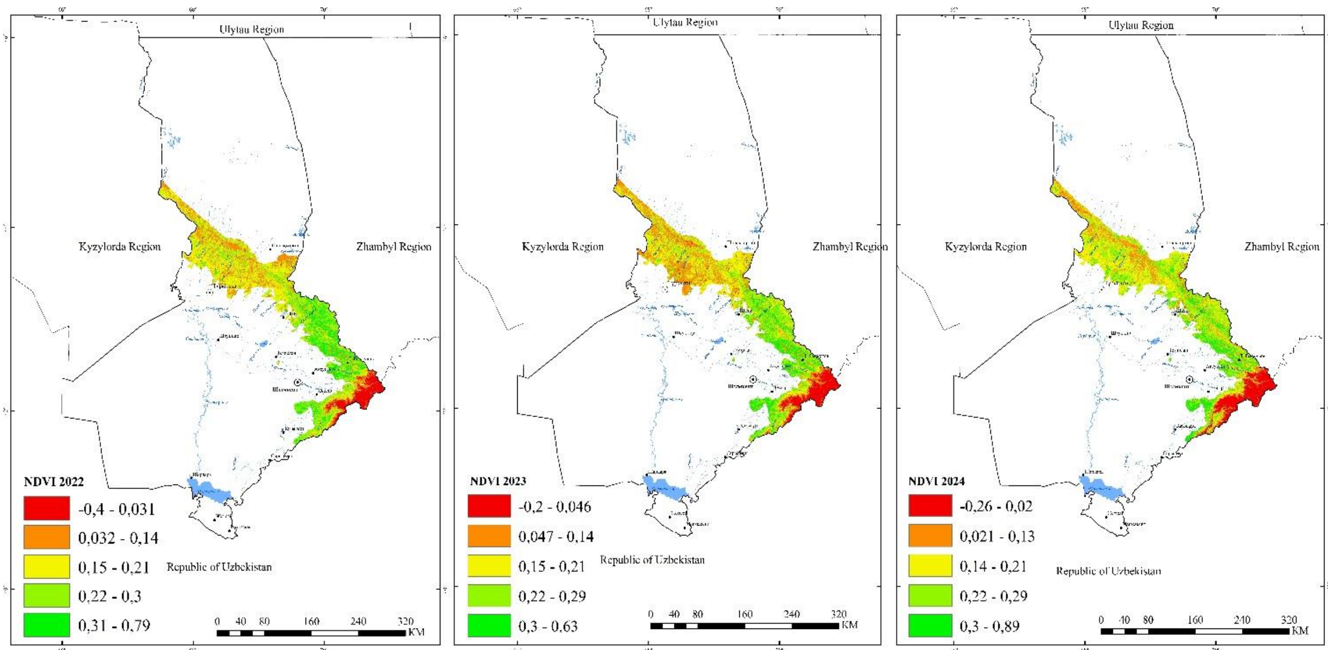

Figure 4. Assessment of Tulipa greigii distribution in the Turkistan Region based on the NDVI index (2022–2024) (Source: Map compiled by the author using Landsat satellite imagery and spatial analysis in ArcGIS (April 2024)

Moisture levels and water stress were assessed using the NDMI index (Figure 5). According to the results, higher NDMI values were observed in natural landscapes with optimal moisture conditions, whereas lower values were associated with agricultural and degraded areas experiencing higher levels of anthropogenic impact.

In Research Site No. 1 (Karatau Range, Karatau State Nature Reserve), NDVI values ranged from 0.31 to 0.79 and NDMI from 0.22 to 0.43 in 2022, indicating good moisture availability and vigorous plant growth. In 2023, NDVI values declined to 0.30–0.63, while NDMI values ranged between 0.14 and 0.33, reflecting the impact of seasonal drought and water deficit. In 2024, NDVI increased to 0.89 and NDMI to 0.29–0.5, demonstrating recovery of vegetation cover and stability of the ecosystem. In Research Site No. 2 (Ordabasy District, Arys River), NDVI values in 2022 ranged from -0.4 to 0.031, and NDMI from -0.56 to 0.008, indicating vegetation degradation and water scarcity. In 2023, NDVI ranged from -0.2 to 0.046, and NDMI decreased to -0.62 to -0.12, signaling further ecosystem decline. In 2024, NDVI dropped again to -0.26–0.02, while NDMI values ranged from -0.37 to -0.02, indicating persistent vegetation stress and degradation.

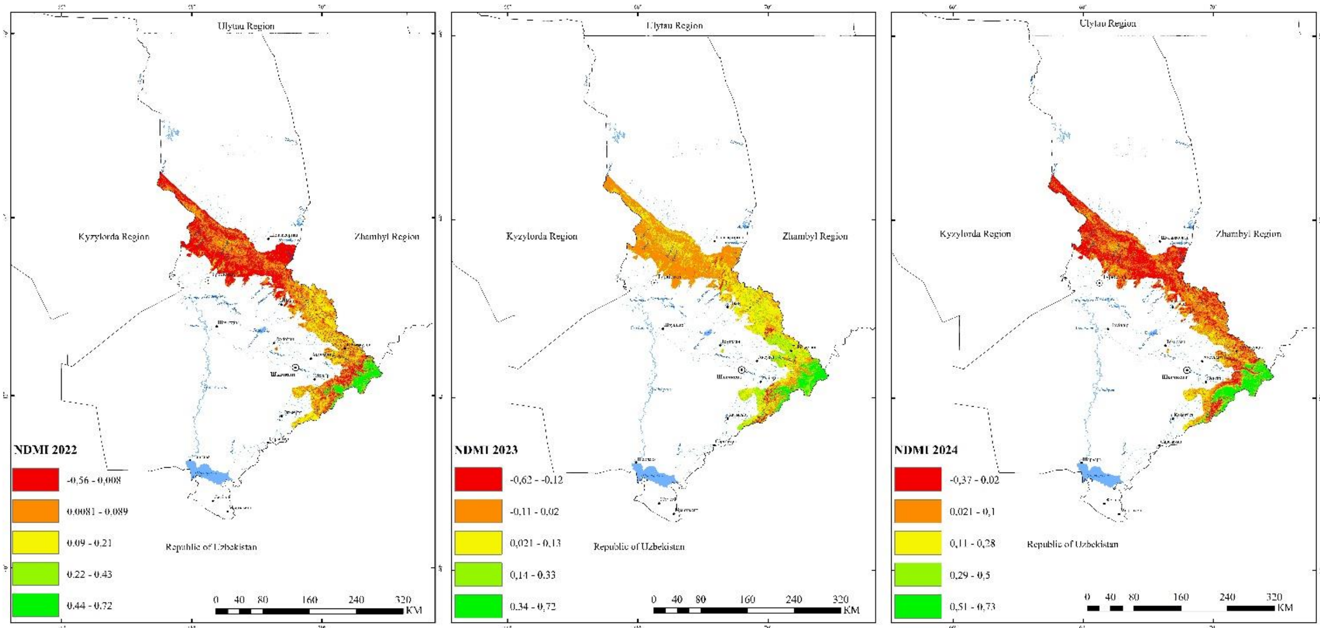

Figure 5. NDMI-based assessment of Tulipa greigii distribution in the Turkistan Region (2022–2024)
(Source: Map compiled by the author using Landsat satellite imagery and spatial analysis in ArcGIS (April 2024)

Additional analyses were conducted to determine the causes of low index values. These were based on satellite images from the Copernicus Sentinel program (2022–2023) and the Apollomapping database (2024) (Figure 6). Comparative analysis revealed that in 2022, during the spring plowing season, *Tulipa greigii* habitats were significantly damaged. In 2023, governmental monitoring and protective measures were implemented. By 2024, enhanced conservation efforts included additional monitoring and ecological stabilization measures.

Figure 6. Tulipa greigii distribution based on Sentinel (2022–2023) and Apollomapping (2024) data

Comparative analysis with satellite imagery and 2024 field data showed that *Tulipa greigii* cover increased by 60–70%, demonstrating the effectiveness of conservation measures. These results highlight the restoration of vegetation cover in some areas while also indicating continued anthropogenic pressure in others. In Research Site No. 3 (Kazygurt Mountain, Kazygurt District), NDVI values in 2022 ranged from 0.22 to 0.79, and NDMI from 0.22 to 0.43, indicating a healthy vegetation cover and sufficient moisture. In 2023, NDVI decreased to 0.22–0.63, while NDMI dropped to 0.14–0.33, likely due to changing climatic conditions. In 2024, NDVI increased to 0.89 and NDMI to 0.29–0.5, reflecting a recovery in vegetation. Although water stress showed seasonal fluctuations, overall vegetation cover remained stable.

In Research Site No. 4 (Shubaykyzyl Highland Area, Tulkibas District), NDVI values in 2022 were between 0.31 and 0.79, and NDMI between 0.22 and 0.43, indicating vegetation stability. In 2023, NDVI decreased to 0.30–0.63 and NDMI ranged from 0.14 to 0.33, suggesting the effects of drought. In 2024, NDVI rose to 0.89, and NDMI ranged from 0.29 to 0.5, indicating vegetation recovery. In Research Site No. 5 (Aksu Valley, Aksu-Zhabagly State Nature Reserve), NDVI in 2022 ranged from 0.22 to 0.79 and NDMI from 0.22 to 0.43, indicating a stable vegetation cover. In 2023, NDVI dropped to 0.22–0.63 and NDMI to 0.14–0.33, reflecting seasonal drought effects. In 2024, NDVI reached 0.89 and NDMI 0.29–0.5, showing favorable moisture conditions for vegetation. This area is favorable for the distribution of *Tulipa greigii*, as the vegetation cover demonstrates resilience and ecological stability. In Research Site No. 6 (Upper Kaskasu, Sairam-Ugam State National Nature Park), NDVI values in 2022 ranged from 0.22 to 0.79 and NDMI from 0.22 to 0.43, indicating stable vegetation cover. In 2023, NDVI decreased to 0.22–0.63 and NDMI ranged from 0.14 to 0.33, reflecting the impact of seasonal drought. In 2024, NDVI rose to 0.89 and NDMI reached 0.29–0.5, indicating ecosystem stability and ongoing recovery processes. In the areas of No. 1 Karatau Range, No. 3 Kazygurt Mountain, No. 4 Shubaykyzyl Highland, No. 5 Aksu Valley, and No. 6 Upper Kaskasu, the vegetation cover remained stable, demonstrating resilience to drought conditions.

In contrast, Research Site No. 2 (Ordabasy District) showed signs of vegetation degradation, high anthropogenic pressure, and significant moisture deficiency. While seasonal drought impacted all regions, signs of vegetation recovery were observed across sites in 2024. These results contribute to identifying areas with adequate vegetation moisture supply, assessing the effects of drought, and determining ecologically favorable zones for the distribution of *Tulipa greigii*.

The long-term dynamics of NDVI and NDMI indicators provide insights into the ecological stability of various regions. These findings offer a valuable scientific basis for future nature conservation planning and forecasting the impacts of climate change. The dynamics of tourism development in the Turkistan Region for the period 2022–2024 (based on indicators from January to June) were also analyzed. According to statistical data, the number of international tourists increased by 45.6%, while domestic tourism rose by 18.5% in 2024, following a temporary decline in 2023. This growth is attributed to the effective utilization of the region's natural landscape potential and infrastructure capabilities (Figure 7) (https://stat.gov.kz/region/turkestan/). The spatial attractiveness of the Turkistan Region and its popularity on social media contribute to the sustainable development of ecotourism. However, there is a need to improve infrastructure and informational support.

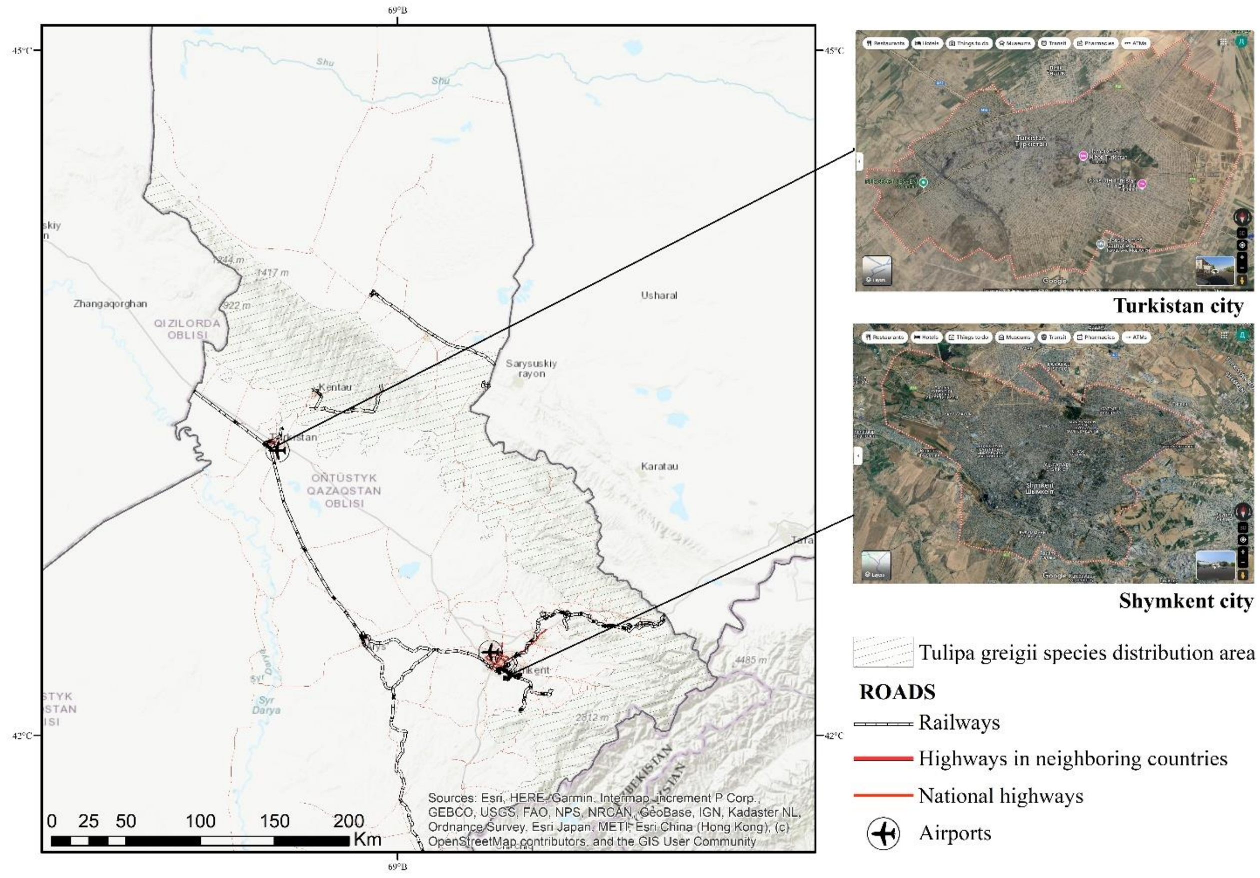

Figure 7. Infrastructure map of the Turkistan Region (Source: Basemap imagery derived from Esri, HERE, Garmin, USGS, OpenStreetMap contributors, and the GIS User Community. Infrastructure layers and road networks were supplemented using Google Maps and validated through field-based observations conducted by the author (April 2024)

An analysis of social media platforms was conducted using the hashtags #GreigiiTulip, #TurkistanTulip, #TulipTurkistan, and #EcotourismTurkistan on TikTok and Instagram (Figure 8). On Instagram, the number of posts with the hashtag #GreigiiTulip decreased from 95 in 2022 to 36 in 2023, and then increased to 71 in 2024. On TikTok, the figures were 49 (2022), 88 (2023), and 57 (2024), reflecting seasonal fluctuations in audience interest.

The hashtag #TurkistanTulip on Instagram reached 59 posts in 2024, an 18% increase compared to 2023. On TikTok, the number of posts was 55 in 2022, 41 in 2023, and 80 in 2024. Both #TulipTurkistan and #EcotourismTurkistan showed growth on both platforms in 2024. In terms of views, TikTok experienced growth across all hashtags in 2024. Specifically, #GreigiiTulip received 1,934 views (up 26%), #TulipTurkistan – 1,989 views (up 18%), and #EcotourismTurkistan – 1,734 views (up 19%). On Instagram, #GreigiiTulip received 1,898 views (a 53% increase compared to 2022), while #TurkistanTulip had 1,875 views (a 5% decrease compared to 2023). Regarding the number of likes, #GreigiiTulip received 762 likes on TikTok (a 12% decrease) and 789 likes on Instagram (a 4% decrease). Meanwhile, #EcotourismTurkistan on TikTok saw 953 likes (up 21%), and #TurkistanTulip on Instagram had 1,091 likes (up 19%).

As for comments, the hashtag #TulipTurkistan reached 528 comments on TikTok in 2024, marking a 49% increase compared to 2023. On Instagram, #TurkistanTulip accumulated 541 comments, a 29% increase. These indicators highlight strong audience engagement with topics related to ecotourism and tulips, and demonstrate the effectiveness of TikTok's hashtag distribution algorithm. From 2022 to 2024, content related to tulips in the Turkistan Region gained steady popularity. Views on TikTok increased significantly for #GreigiiTulip and #TulipTurkistan, while on Instagram, #TurkistanTulip led in terms of likes. On TikTok, #TulipTurkistan became a trending hashtag in terms of comments.

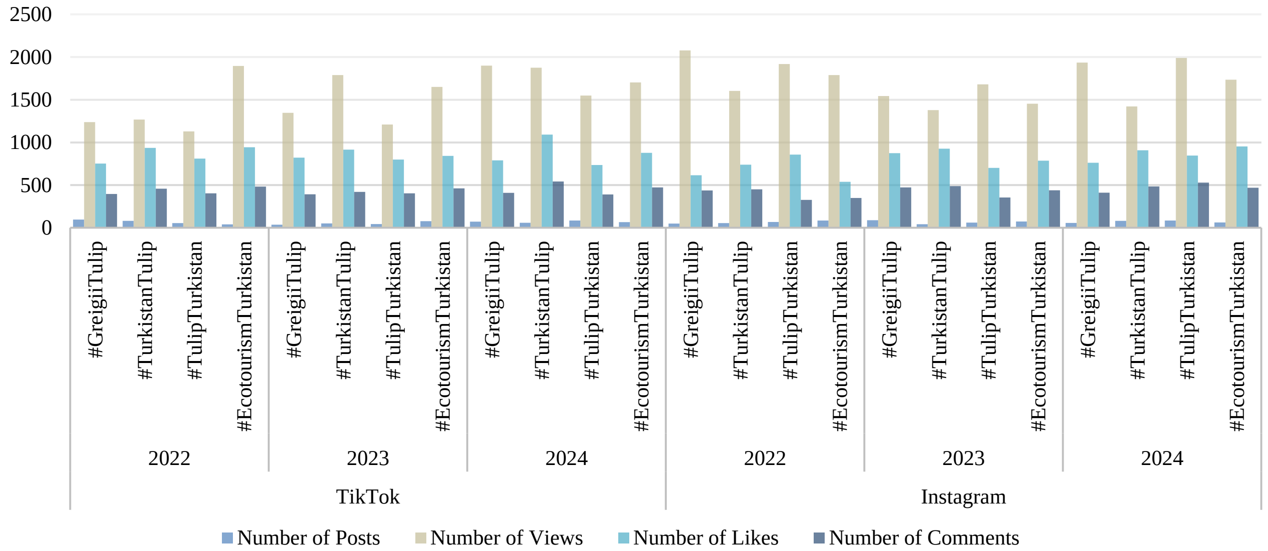

Figure 8. Social media analysis of hashtags related to Tulipa greigii on TikTok and Instagram (Source: Data were manually collected in April 2024 from public TikTok and Instagram posts using hashtags #GreigiiTulip, #TulipTurkistan, and #EcotourismTurkistan)

To enhance outreach, it is recommended to improve TikTok content strategies and establish more consistent content on Instagram. The popularity dynamics of ecotourism areas in the Turkistan Region are as follows: Karatau Range, Karatau State Nature Reserve – This area attracts mountain tourism enthusiasts; however, its popularity remained steady between 2022 and 2024. Ordabasy District, along the Arys River – Domestic tourism has shown notable development. While popularity was low in 2022, it increased by 50% in 2023 and reached 75% in 2024, reflecting growing interest in ecotourism in the region. Kazygurt Mountain, Kazygurt District – The area maintained stable popularity from 2022 to 2024. Despite its unique tulip species and natural features, it remains underrepresented on social media and in tourism promotion programs. Shubaykyzyl Highland Area, Tulkibas District – This site was especially popular in 2022–2023. However, its popularity declined in 2024 due to the implementation of restrictions following its designation as a protected area.

Aksu Valley, Aksu-Zhabagly State Nature Reserve – One of the key destinations for mountain tourism. In 2022, its popularity was moderate (50%), with steady growth in 2023–2024 reaching 60%.

Upper Kaskasu Area, Sairam-Ugam National Nature Park – Popularity stood at 60% in 2022, increasing to 65% in 2023 and reaching 70% in 2024. This area continues to attract steady interest from ecotourists.

The study results identified the ecotourism potential of the Turkistan Region and emphasized the need to develop tourism routes related to *Tulipa greigii*. The rising popularity of the region's natural landscapes on social media supports the promotion of ecotourism; however, improvements in infrastructure and informational support are still required (Ilies et al., 2022). In this regard, the implementation of the following recommendations will contribute to the sustainable development of ecotourism: Development of a "Tulip Route": It is recommended to design dedicated tourist routes that encompass the main ecotourism sites of the Turkistan Region, including the Shubaykyzyl Gorge, Sairam-Ugam National Park, and Kazygurt Mountain. This route would allow for the exploration of tulip habitats through organized eco-tours while incorporating nature conservation measures. Strengthening conservation measures: To preserve the ecological significance of tulips, it is proposed to organize a "Tulip Festival." This event would promote the protection of natural tulip habitats and raise the ecological awareness of local communities. In addition, wide coverage of the festival through social media platforms would help promote the biological importance of tulips.

Developing a social media strategy: To promote ecotourism in the Turkistan Region, it is recommended to launch targeted ecotourism campaigns on popular platforms such as TikTok and Instagram. Collaborating with bloggers and eco-tourism influencers to produce multimedia content showcasing the region's natural landmarks can increase tourist flow. Improving tourism infrastructure: In areas such as the Shubaykyzyl Gorge and Kazygurt Mountain, it is necessary to develop recreational zones, install directional signage, and place informational billboards to ensure a comfortable experience for ecotourists. These actions are essential for ensuring tourist safety and maintaining ecological sustainability. By implementing the above measures, it is possible to develop sustainable ecotourism in the Turkistan

Region centered around *Tulipa greigii*. This will not only contribute to the conservation of biodiversity but also enhance the region's touristic appeal and positively impact the local economy.

CONCLUSION

The study identified the spatiotemporal distribution characteristics of *Tulipa greigii* within the natural landscapes of the Turkistan Region. The species' distribution and habitat conditions were assessed using NDVI and NDMI indices, which helped determine vegetation status and moisture availability across different research sites.

In the areas of Karatau, Kazygurt, Shubaykyzyl, and Aksu Valley, NDVI values ranged from 0.63 to 0.89 and NDMI from 0.29 to 0.5, indicating ecological stability of habitats. In contrast, the Ordabasy District recorded low NDVI (-0.26 to 0.02) and NDMI (-0.62 to -0.02) values, reflecting intensified degradation processes.

Official statistical data from 2022 to 2024 showed consistent growth in ecotourism within the Turkistan Region.

The number of inbound (international) tourists increased by 45.6%, and domestic tourism rose by 18.5% in 2024 following a temporary decline in 2023. This growth reflects the effective utilization of the region's natural landscape features and infrastructure potential. Hashtag analysis on social media platforms indicated increasing public interest in *Tulipa greigii* and ecotourism. In 2024, the number of posts, views, and comments using hashtags such as #GreigiiTulip, #TulipTurkistan, and #EcotourismTurkistan grew across TikTok and Instagram, confirming audience engagement with ecotourism topics. The #TulipTurkistan hashtag reached 528 comments on TikTok, a 49% increase, while #TurkistanTulip garnered 1,091 likes on Instagram in 2024, showing a 19% rise. These results highlight the informational influence of social media and its importance in promoting ecotourism.

The conducted spatiotemporal analysis confirmed that the distribution of tulips and ecosystem stability are directly influenced by climatic and anthropogenic factors. The study outcomes can serve as a basis for developing comprehensive strategies in ecological monitoring, conservation of natural populations, and the sustainable development of ecotourism.

If you have any suggestions or feedback, we are open to considering them with great care—your input is important to us and contributes to the expansion of our scientific perspective. This study was conducted based on the integration of spatiotemporal modeling, satellite remote sensing data, field survey results, and social media information obtained from digital platforms. However, several methodological limitations were identified.

First, the ecological assessment of *Tulipa greigii* distribution was limited to field expeditions conducted during the flowering period (April), which does not allow for capturing the full spectrum of seasonal dynamics.

Second, the social media data were based on user digital engagement and do not reflect actual ecotourism flows, potentially limiting the representation of structural patterns of regional tourism.

Third, the relationship between landscape structure and anthropogenic factors was assessed indirectly using spatial indices and visual interpretation, which may require broader analysis if complemented by detailed local socioeconomic data.

Author Contributions: Conceptualization, A.N.D. and D.S.A.; methodology, A.N.D. and D.S.A.; software, A.N.D.; validation, A.N.D. and D.S.A.; formal analysis, A.N.D. and D.S.A.; investigation A.N.D. and D.S.A.; data curation – A.N.D. and D.S.A.; writing - original draft preparation, A.N.D. and D.S.A.; writing - review and editing, D.S.A.; visualization, A.N.D.; supervision, A.N.D.; project administration, D.S.A.. All authors have read and agreed to the published version of the manuscript.

Funding: Not applicable.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study may be obtained on request from the corresponding author.

Acknowledgements: The authors would like to express their gratitude to colleagues and local experts for their support in organizing fieldwork and for providing valuable comments during the research process.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

Akhmetova, D. S., Saginov, K. M., Yeginbayeva, A. Y., Arykbaeva, K. M., & Kenzhebay, R. N. (2024). Analysis of landscape structures of the Turkestan region. *News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences*, 6(467), 32–48. https://doi.org/10.32014/2024.2518-170X.459

Berdenov, Z. G., Mendybayev, E. H., Ataeva, G. M., & Dzhanaleeva, G. M. (2015). Landscape and geochemical features of man-made pollution zones of Aktobe agglomerations. *Oxidation Communications*, 38(2), 852–859. https://doi.org/10.26577/jgem.2015.2.251

Bureau of National Statistics of the Republic of Kazakhstan. (2024). Statistical data on Turkestan region. (Accessed: 29.12.2024). https://stat.gov.kz/region/turkestan/

Christenhusz, M. J. M., Govaerts, R., David, J. C., Hall, T., Borland, K., Roberts, P. S., Tuomisto, A., Buerki, S., Chase, M. W., & Fay, M. F. (2013). Tiptoe through the tulips – Cultural history, molecular phylogenetics, and classification of Tulipa (Liliaceae). *Botanical Journal of the Linnean Society*, 172(3), 280–328. https://doi.org/10.1111/boj.12061

Debnath, J., Saha, S., Sharma, R., Tiwari, K., & Deka, P. (2023). Geospatial modeling to assess the past and future land use-land cover changes in the Brahmaputra Valley, NE India, for sustainable land resource management. *Environmental Science and Pollution Research*, 30, 106997–107020. https: https://doi.org/10.1007/s11356-022-24248-2

Debnath, J., Shit, P. K., Bhunia, G. S., & Maiti, R. (2023). Geospatial modeling of land use/land cover change and its impacts on ecological parameters in Northeast India. *Environmental Science and Pollution Research*, 30, 106997–107020. https://doi.org/10.1007/s11356-023-28023-3

Eker, İ., Serdar, B., & Tekşen, M. (2024). Phylogeny and infrageneric classification of tulips (Tulipa L., Liliaceae) based on molecular data. *Plant Systematics and Evolution*, 310(4), 23. https://doi.org/10.1007/s00606-024-01856-1

Eker, İ., Tarıkahya Hacıoğlu, B., & Özgişi, K. (2024). Phylogeny and infrageneric classification of tulips. *Plant Systematics and Evolution*, 310(4), 23. https://doi.org/10.1007/s00606-024-01907-0

Hoog, M. H. (1973). On the origin of Tulipa. In Lilies and Other Liliaceae. *Royal Horticultural Society*, 47–64. https://doi.org/10.1007/BF00982313

Ilies, G., Ilies, M., Hotea, M., Bumbak, S. V., Hodor, N., Ilies, D. C., Caciora, T., Safarov, B., Morar, C., Valjarević, A., Berdenov, Z., Lukić, T., Mihajlović, M., Liudmyla, N., & Vasić, P. (2022). Integrating forest windthrow assessment data in the process of windscape reconstruction: Case of the extratropical storms downscaled for the Gutai Mountains (Romania). *Frontiers in Environmental Science*, 10, 926430. https://doi.org/10.3389/fenvs.2022.926430

Ionescu, M. F., & Tătar, C. (2016). The tourist map as a tool for protected area exploration. *GeoSport for Society*, 4(1), 24–32. https://geosport.uoradea.ro

Ivashchenko, A. A., & Belyalov, O. V. (2019). Kazakhstan is the Birthplace of Tulips. *Atamura Publishing House*. https://doi.org/10.3897/phytokeys.250.136736

Kubentayev, S. A., Artykbayeva, S. T., Abugalieva, A. I., Baiseitova, L. Z., Turdybek, A. A., & Zhubatkanov, A. K. (2024). Revisiting the genus Tulipa in Kazakhstan, the country with the richest tulip diversity worldwide. *PhytoKeys*, 250, 95–163. https://doi.org/10.3897/phytokeys.250.136736

Kubentayev, S. A., Baasanmunkh, S., Alibekov, D. T., Tojibaev, K. S., Nyamgerel, N., Ivashchenko, A. A., Tsegmed, Z., Epiktetov, V. G., Sitpayeva, G. T., Izbastina, K. S., Idrissova, Z. T., Mukhtubayeva, S. K., Abubakirova, N. B., Gil, H. Y., & Choi, H. J. (2024). Revisiting the genus Tulipa (Liliaceae) in Kazakhstan, the country with the richest tulip diversity worldwide. *PhytoKeys*, 250, 95–163. https://doi.org/10.3897/phytokeys.250.136736

Liu, Y., Li, Y., Li, S., & Motesharrei, S. (2015). Spatial and temporal patterns of global NDVI trends: Correlations with climate and human factors. *Remote Sensing*, 7(10), 13233–13250. https://doi.org/10.3390/rs71013233

Lykhovyd, P. V., & Sharii, V. O. (2024). Normalised difference moisture index in water stress assessment of maize crops. *Agrology*, 7(1), 21–26. https://doi.org/10.32819/202403

Orlikowska, T., Nowakowska, K., Marasek-Ciolakowska, A., & Pacholczak, A. (2018). Tulip. In Ornamental Crops, 769–802. https://doi.org/10.1007/978-3-319-90698-0_28

Pavord, A. (1999). The Tulip: The Story of a Flower That Has Made Men Mad. St. Martin's Press.

Pettorelli, N., Vik, J. O., Mysterud, A., Gaillard, J. M., Tucker, C. J., & Stenseth, N. C. (2005). Using the satellite-derived NDVI to assess ecological responses to environmental change. *Trends in Ecology & Evolution*, 20(9), 503–510. https://doi.org/10.1016/j.tree.2005.05.011

Sutula, M., Kakanay, A., Tussipkan, D., Dzhumanov, S., & Manabayeva, S. (2024). Phylogenetic analysis of rare and endangered Tulipa species (Liliaceae) of Kazakhstan based on universal barcoding markers. *Biology*, 13(6), 365. https://doi.org/10.3390/biology13060365

Sutula, M., Zubkova, N., Akinina, M., Logacheva, M., Shipunov, A., & Speranskaya, A. (2024). Phylogenetic analysis of rare and endangered Tulipa species in Kazakhstan. *Biology*, 13(6), 365. https://doi.org/10.3390/biology13060365

Tojibaev, K., Dekhkonov, D., Ergashov, I., Sun, H., Deng, T., & Yusupov, Z. (2022). The synopsis of the genus Tulipa (Liliaceae) in Uzbekistan. *Phytotaxa*, 573(2), 163–214. https://doi.org/10.11646/phytotaxa.573.2.2

Vvedensky, A. I., & Kovalevskaya, S. S. (Eds.). (1971). Tulipa L. Conspectus Florae Asiae Mediae, 2, 94–109, *Publishing House of the Academy of Sciences of the Uzbek SSR*. [In Russian] https://doi.org/10.4236/ajps.2020.115053

Article history: Received: 23.03.2025 Revised: 25.06.2025 Accepted: 11.07.2025 Available online: 01.08.2025